Review of recent forest research projects on climate change and CO_2 concentration in Europe

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ABSTRACT

Climate change can be defined as the long-term fluctuations in temperature, precipitation, wind and all other aspects of the earth's climate often related to the term greenhouse effect. Climate change is not a new phenomenon. The climate has been continuously changing, acting as driving force for biotic and abiotic evolution. The new aspects of climate change we are confronted with, are the timescales within which the change is taking place and human induced disturbances.

Considering the relevance of climate change and CO_2 concentration increase on forest growth, and the effects that changes could have on future land use and use of forests, it is not surprising that many studies, on this subject, have been carried out all over the world. Nevertheless sometimes it is difficult to find specific information or to know who is working on a specific subject because of this vast amount of research.

Thus, the aim of this report is to demonstrate what kind of research has been carried out under way on the impacts of climate change and increasing CO_2 concentration on forests in Europe. The report aims to present the main European and National studies, but does not provide a complete listing of all the studies. Therefore the author welcomes all the additions to this report.

Concerning the EU funded projects, 11 projects have been listed on several fields: forest response to environmental stress, predicted impact of rising CO_2, ecological effects of land-use changes on mountain ecosystems and so on. All these projects cover a time since 1996 till 2000 and some of them are not yet concluded.

In the national projects were found 8 projects for Belgium, 1 for Denmark, Ireland, Portugal and United Kingdom, 2 for Finland and Italy, 3 for Netherlands and Switzerland, 4 for Germany. Even for National projects not all of them are concluded and all together they cover a time range since 1990 till 2000.

This review could be considered like a tool for future research in the field of Climate Change. Indeed a short description is given for each project and, for the most of them, it is also indicated where it is possible to find more information on Internet. In addition, also the name and addresses of contact people are given in order to facilitate the contacts between different working groups.

1. INTRODUCTION

Climate change can be defined as the long-term fluctuations in temperature, precipitation, wind and all other aspects of the earth's climate often related to the term greenhouse effect. Climate change is not a new phenomenon. The climate has been continuously changing, acting as driving force for biotic and abiotic evolution. The new aspects of climate change we are confronted with, are the timescales within which the change is taking place and human induced disturbances.

For millions of years the unavoidable greenhouse effect has played a basic role in determining the Earth's climate; without the "natural" greenhouse effect the Earth's average temperature would be 18 degrees Celsius below zero and Earth would be a lifeless, frozen wasteland. Instead, the "natural" greenhouse effect raises the Earth's average temperature to 33 degrees Celsius, allowing plants to grow and soils to form and sustain biodiversity. Thus, as plants and soils absorb carbon dioxide and other greenhouses gases from the atmosphere, for millions of years a combination of biological and hydrological systems released just enough carbon dioxide to maintain a fairly stable balance of these gases in the atmosphere.

Research carried out during the last 40-50 years has discovered an enormous disruption in the global carbon cycle and a notable rising of most greenhouse gases; carbon dioxide levels have increased by about 25% since 1850, methane levels by 100% and nitrous oxide levels by 15%. The recent occurrence of extreme weather events suggests that the world's climate is, indeed, being disrupted in a manner consistent with the increased level of greenhouse gases in the Earth's atmosphere. Human induced changes in the global climate has been also stated in the assessment reports of the Intergovernmental Panel on Climate Change (IPCC 1990, 1992, 1995).

IPCC reports in 1990 and 1992 estimated that some of the possible effects of rapid global warming could be:

- large-scale disruption of forestry, agriculture and fisheries;
- extinction of many plant and animal species on land and in the oceans;
- changing rainfall patterns;
- loss of huge tracts of coastal land under rising seas, as the oceans expand;
- less access to less reliable water supplies in many parts of the world;
- serious adverse effects on human health.

Moreover, concerning the impact on forests, it is possible that many tree species will not be able to change their geographic distribution as fast as the projected shifts in suitable climate and extinction may occur. Forests themselves affect the microclimate by lowering summer temperatures and preventing soil from drying out; they reduce heat loss from the ground in winter and prevent the occurrence of wind storms. Moreover by regulating the global carbon cycle forests have a profound effect on the global climate.

European annual mean air temperatures have increased by 0.3 - 0.6 degrees Celsius since 1900. Climate models predict further increases of about 2 degrees Celsius, above 1990 levels, by the year 2100, with higher increases in the North of Europe than in the South (IPCC 1995).

To ensure that further temperature increases are not more than 0.1degrees Celsius per decade would require industrialised countries to reduce emissions of greenhouses gases by at least 30-55% from 1990 levels by 2010. Such reductions are much higher than the commitments made by the industrialised countries at the third conference of parties of the United Nations Framework Convention on Climate Change (UNFCCC) in Kyoto in December 1997. The overall greenhouse gas emissions of the six greenhouse gases included in the Kyoto Protocol (FCCC/CP/1997/L.7/Add.1) should reduce in the industrialised countries at least by 5% below the 1990 level during the first commitment period 2008-2012. Reduction target for the most European countries is 8% below the 1990 levels by 2010.

Nevertheless it has to be considered that carbon dioxide is also released into the atmosphere when forests are cleared using fire in tropical countries such as Brazil and Indonesia, and as exposed forest soil decomposes. The agricultural crops which usually replace tropical forests have a far lower capacity to store carbon.

Considering the relevance of climate change and CO_2 concentration increase on forest growth, and the effects that changes could have on future land use and use of forests, it is not surprising that many studies, on this subject, have been carried out all over the world. Nevertheless sometimes it is difficult to find specific information or to know who is working on a specific subject because of this vast amount of research.

Thus, the aim of this report is to demonstrate what kind of research has been carried out oris under way on the impacts of climate change and increasing CO_2 concentration on forests in Europe. The report aims to present the main European and National studies, but does not provide a complete listing of all the studies. Therefore the author wishes all the additions welcome to this report.

Concerning the EU funded projects, 11 projects have been listed on several fields: forest response to environmental stress, predicted impact of rising CO_2, ecological effects of land-use changes on mountain ecosystems and so on. In the national projects were found 8 projects for Belgium, 1 for Denmark, Ireland, Portugal and United Kingdom, 2 for Finland and Italy, 3 for Netherlands and Switzerland, 4 for Germany.

Moreover, there are several groups all around Europe working about the Global Change and its several consequences on ecosystems. Some of these groups are involved in the "Global Change and Terrestrial Ecosystems (GCTE) programme, which is one of the core programmes of the "International Geosphere-Biosphere Programme (IGBP)".

The *International Geosphere-Biosphere Programme* (IGBP) is an interdisciplinary scientific activity established and sponsored by the *International Council for Science* (ICSU). The Programme was instituted by ICSU in 1986, and the IGBP Secretariat was established at the Royal Swedish Academy of Sciences in 1987. GCTE aims to develop a predictive understanding of the effects of changes in climate, atmospheric composition, and land use on terrestrial ecosystems (both natural and managed), and to determine feedback effects to the atmosphere and the physical climate system. Ecosystem responses are being investigated both through manipulative studies and long-term studies at selected sites. Modelling studies are focused on the construction of dynamic vegetation and agricultural systems models at a variety of scales, both for linking to global biogeochemical models and physically based GCMs and for direct impact studies. Inside the IGBP there is also a group of leading scientists from a range of disciplines associated with national and global carbon budgets relevant to the Kyoto Protocol. The objectives of this group are to:

- discuss the scientific issues and implementation problems associated with the current Kyoto protocol,
- document the components and processes associated with a complete accounting of terrestrial carbon sources and sinks,
- propose and assess methodologies for measuring these components and processes, and
- discuss implications of the science for the protocol development process.

2. PREDICTED CHANGES IN THE CLIMATE AND ENVIRONMENT AND LIKELY IMPACTS ON FORESTS

2.1 INTRODUCTION

Climate and atmospheric deposition of nutrients are important ecosystem driving variables that affect ecosystem processes such as primary production and decomposition. These feed directly back into climate and atmospheric systems by modifying fluxes of water and "greenhouses" gases such as CO_2, CH_4, and NO_2. These interactions, which result in immediate changes in climatic properties, can be referred to as "direct feedback effects" and they include, for instance: 1) net C fluxes via plant production and decomposition; 2) biogenic trace gas exchange controlled by nutrient cycling processes (denitrification, leaching, methanogenesis, biomass combustion); 3) water and energy fluxes via evapotranspiration, run-off and run-on.

Changes in the rates of these ecosystem processes directly influence the rates of change in the global environment, by modifying land surface properties and the radiant balance of atmosphere. These processes can be characterised as having a high sensitivity to changes in the environment and relatively fast response times.

Another class of interactions are represented by the "indirect feedback effects" between natural ecosystems and global climate. An example of this category is the modifications of biophysical characteristics on the land surface, caused by a shift from forest to savannah-woodlands or grasslands.

Changes in the structure of vegetation alters the roughness and reflectivity of the land surface and can potentially modify local, regional and global-scale climate through changes in albedo, humidity and ground-level wind patterns. Changes in plant communities can also modify litter quality, carbon and nutrient allocations and lead to feedback in the climate system. Indeed the soil of boreal forests is a large carbon store and the amount of C is still increasing in young soils, which makes these soils an important sink for atmospheric CO_2. Since the processes defining the soil C balance, primary production of plants and decomposition, are dependent on environmental factors and site properties, the organic carbon pool in the soil is also dependent on the same factors. The soil C store is therefore likely to change in response to climatic warming (Ojima et al. 1991).

Next sections presents briefly the main ecological factors involved in Climate Change and the possible impacts on forests and trees.

2.2 CO_2

The global air concentration of carbon dioxide was stable at 280 ppm for about 1000 years before the beginning of the 20th century. Thus fluctuations of carbon storage must have occurred, the forest ecosystem on the global scale were near a steady-state.

In about 1800, the CO_2 concentration started rising, first slowly, then faster reaching the current level of about 360 ppm. The change in 19th century was mainly due to land clearing. The clearance rate has not decreased globally in the 20th century, however, the relative contribution of deforestation as a CO_2 source has declined, because the consumption of fossil fuels has increased enormously.

CO_2 is by far the most abundant of the greenhouses gases; current estimates are that human activities are contributing approximately 7 billions tons of carbon as CO_2 and other greenhouses gases to the atmosphere every year.

Most of the past and present emissions of greenhouse gases come from the combustion of fossil fuels. However, share of land-use changes (namely clearing of tropical forests to other uses) is about 20% of all the human induced CO_2 emissions (Schimel 1995). The main contribution of agriculture and forestry to the greenhouse effect concern the emission of carbon dioxide, methane and nitrous oxide, whereas the emission of nitric oxide and carbon monoxide are less relevant. Most of the net carbon dioxide contribution comes from permanent deforestation (about 25% of the total net annual increment) but large quantities are released also through shifting agriculture. Half of the annual CO_2 flux remains in the atmosphere, the other half appears to be absorbed in the oceanic sink, although substantial uncertainty remains about balancing the global carbon budget.

The storage of CO_2 in the atmosphere is an important variable in the global ecology, as CO_2 is the main substrate for photosynthesis. The elevated CO_2 concentrations connected to climate change are likely to affect the photosynthetic processes in plants. Depending on the kind of plant, the long-term responses of photosynthesis vary. It is believed that, in the case of coniferous trees, the response will either be positive or of no consequence (Second World Climate Conference 1990).

The greenhouse gases vary greatly both in their active residence time in the atmosphere before they are decomposed, as in their radiative forcing relative to CO_2; the latter is considered as the standard against which the radiative properties of other gases are compared.

For example, methane is a relatively short-lived gas, so emissions from biomass burning or soils exposed by deforestation would have their greatest impacts on climate forcing during the first decades following release. However, nitrous oxides released by soils from the same deforestation event would contribute to climate forcing for hundreds of years, since they are more stable and decompose very slowly in the atmosphere.

Most early studies of possible climate-induced perturbations of forests, have used standard atmospheric General Circulation Models (GCMs) of global climate to predict changes in regional temperature and moisture regimes, and their consequences for forest growth and distribution under a doubling CO_2 scenario. Such models utilise laws of physics that determine climate, expressed as mathematical equations, to quantify relationships among variables such as temperature, precipitation, pressure and various gas cycles in the global system.

Impacts on forests and trees

Laboratory studies of the effects of elevated CO_2 levels on plants have documented increased rates of photosynthesis, lowered plant water use requirements, increased carbon sequestering and increased soil microbial activity fixing nitrogen for fertiliser, thereby stimulating growth. However, the degree of response varies greatly, depending on species, growing conditions, mineral nutrition and duration of CO_2 enrichment.

After a period of exposure to elevated CO_2, some but not all species reduce the rates of CO_2 assimilation as a result of acclimation. This seems to be associated with limitation of shoot growth, which might be species characteristic, or induced by poor environmental conditions (Ceulemans 1997). Review of hundreds of such lab studies has concluded that a projected doubling of CO_2 will increase growth and yield by 34% (+/- 6%) for plants in which photosynthesis proceeds via the C3 pathway. For the less abundant but economically important C4 plants, the rise will be around 14% (+/- 10%). More and more experience is accumulating from field experiments, where trees are exposed to higher atmospheric CO_2 and temperature conditions (see for example later ECOCRAFT project).

There has been relatively little attention paid to the effects of elevated CO_2 on Mediterranean trees. In a recent review of the effects of elevated CO_2 on plant growth, Poorter et al. (1996), reported data on 174 tree species and only three could be considered native to regions with the Mediterranean type of climate, in any case, exposure to elevated CO_2 lasted only a short period (2-4 months). The work of Pereira and Chaves (1997) provides an exception. Their study examines the effects of elevated CO_2 on growth of *Quercus suber* seedlings for two growing seasons. Some of the results obtained suggest that Mediterranean trees do not differ from Temperate-zone ones in terms of growth response to elevated CO_2: the growth enhancement seems to be short-lived after exposure to elevated CO_2, down-regulation of photosynthesis occurs after some time at elevated CO_2 and nitrogen availability in the soil interacts with elevated CO_2. Increasing atmospheric CO_2 may also influence the chemical composition of plants, litter quality, and subsequently litter decomposability.

Many short-term experiments have indicated that plant material grown at elevated CO_2 levels tended to have higher contents of non-structural carbohydrates, like starch and sugar, of structural carbohydrates like lignin and cellulose, as well as of some secondary metabolites like polyphenols, and lower contents of nutrients, in particular nitrogen. Such changes in litter quality may decrease the turnover rates of carbon and nitrogen in the soil, at least in the short-run. On the other hand, increased formation of easily decomposable non-structural compounds, like starch would stimulate microbial activity, and would enhance N immobilisation by soil microbes. This could then lead to a slower recycling of plant material through decreased soil N availability (Gahrooee 1998).

2.3 TEMPERATURE

Major study methods used to investigate relations between climate change and forest growth include: those looking at correlations between tree species distribution and climate, for instance, studies correlating modern pollen distributions of indicator species with monthly temperature and annual precipitation; reconstructing past pollen distributions from GCM (General Circulation Model) simulation of past climates, consequently taking GCM scenarios of doubled CO_2 to predict pollen and tree distribution in the future; computer simulation models of forest dynamics, where standard forest stand models are used to model the growth characteristic of individual trees, gap-phase dynamics and stand composition changes over time; fossil record studies. Possible analogies of future warming have been developed from reconstruction of the fossil pollen record during the past 10,000 - 100,000 years, usually focusing on the interglacial warm period of 5,000 - 9,000 years ago; Holdridge Life Zone classification studies, yielding estimates of changes in biomass, carbon and/or forested area.

These are not, of course, all of the methods used in this type of study and it would be impossible to quote all of them; nevertheless it possible to give some indications about several simulation models valid for European forests. One such example is the "simulation model for the transient effects of climate change on forest landscapes", developed by Prentice et al. (1992) for forests in central Sweden. The dynamics of forest landscapes are simulated in a changing environment, with simple phenomenological equations for the tree growth processes and local environmental feedbacks.

Assuming that temperature and precipitation are the major variables of the niche occupied by a tree species Väisänen et al. (1993) have developed a "model for simulating the effects of changing climate on the functioning and structure of the boreal forest ecosystem". They have coupled the long-term dynamics of the forest ecosystem with climate, trough physiological mechanisms such as photosynthesis and respiration in terms of energy flow through the ecosystem.

As climatic change in the form of higher temperatures and more precipitation could increase the productivity of the forest ecosystem and lead to higher rates of regeneration and growth, more frequent and intensive thinnings are needed, to avoid the mortality of trees induced by accelerating maturation and attacks of fungi and insects. This is indicated in the "model computations on the impacts of climatic change on the productivity and silvicultural management of the forest ecosystem" developed by Kellomäki et al. (1988), which pays particular attention to the situation in Finland.

Impacts on forests and trees

Recent research suggests that global warming will have severe and rapid effects on forest over large areas, all other factors being equal (Botkin and Nisbet 1990). For vegetation the possible consequences of a future global climatic change induced by an increase of atmospheric greenhouse gas concentrations, and especially a large rise of the global mean temperature, are mainly dependent on the magnitude and the rate of the changes within the main climatic parameters, particularly temperature and precipitation (Kauppi 1995).

Projections suggest that effects might be so great that forest production and species composition will change over large regions, and forests in many regions may no longer be sustainable. Such responses would lead to major impacts on commercial forestry, timber supply, recreation and wildlife depending on forest habitats, as well as on water supply and erosion.

Plant growth and health may benefit from increased temperatures because of reduced frost and chilling damage, but plants may be harmed by increased high-temperature damage. On the other hand increasing temperature raises evaporative demand; if rainfall does not increase, more severe water stress will be the result, which will adversely affect growth and may increase the risk of drought and fire. Net primary productivity is generally enhanced by modest increases in temperature, especially in temperate and boreal regions. Forest community composition is likely to be changed, as species and genotypes more tolerant of water stress, warmer temperature, pests infestations, fire, and more frequent extremes of wind, temperature, drought or flood out compete species and/or provenances at the Southern edges of their range, or are unable to adapt to these alterations.

One expected effect of global warming on forest trees in the boreal and alpine areas is that the onset of bud burst will be advanced by milder winters and warmer springs. This could result in increased wood production on the one hand, and in increased risk of late frost damage on the other hand (Hänninen 1991) for central Finland. However, cold winters in the boreal zone have protected forests and trees from insect damages and fungi infestations which are more common in warmer regions. This may change as a consequence of warmer climate.

Warming is already having a significant effect on plant ecology. Indeed Murray et al. (1989) found that the survival of Sitka spruce (*Picea sitchensis*) in Britain is improving with the increasing of atmospheric CO_2 concentrations in conjunction with climatic warming, due to reducing the risk of spring and autumn frost damage and lengthening the potential growing season. The spring frost probability for trees will also decrease in the Netherlands and in Germany.

The differences in the results obtained in these two studies may be caused by different species characteristics and different climatic warming scenarios used.

Another effect of climatic warming may be an altered competitive balance between tree species if species differ in their temperature response in terms of the onset and cessation of growth and consequently in the duration of the growing season. These effects may influence the survival and eventually the distribution of trees, because of a lack of adaptation to an altered environment. Little adjustment can be expected from a change in the genetic composition of tree species by natural selection, if the climate changes within the life span of individual trees. Changes in forest structural composition and possible inhibition of forest biomass formation raise problems of sequestration facilities of enhanced CO_2 by forests in the future.

Some studies, carried out for the Estonian forests and simulating different scenarios, suggest that *Pinus sylvestris*, having a broad ecological area of distribution, showed the highest tolerance to climate warming and decreasing amount of precipitation (Mandre et al. 1995). An increase of the mean temperature by 4 ºC and of precipitation by 10%, may also result in an increase of the biomass of several deciduous tree species (*Betula* spp., *Quercus robur, Populus tremula*).

2.4 PRECIPITATION

Due to the large natural variability of precipitation in time and space, changes of precipitation are more difficult to generalise than those of temperature. Present-day climate models project an increase in global mean precipitation of about 3-15% with a temperature increase of 1.5-4.5ºC. There are likely to be regions where precipitation will increase by more than the global average and where the additional rainfall may be more than sufficient to meet increased evaporative demand, whereas other regions may receive less rainfall than at present; this is further complicated by feedbacks from the biosphere. For instance Heino (1994) compared the spatial distributionof the annual mean precipitation in Finland for the latest normal period 1961-90 with the previous normal period 1931-60. The annual mean precipitation has increased in Finland between the two latest normal periods. A similar study was carried out by Førland et al. (1996) for the whole North Atlantic region. The study indicated that the annual precipitation has clearly increased in the western parts of UK, Netherlands, Germany, Denmark, Sweden and Norway. These are all areas exposed to orographic precipitation from humid westerlies. However there are also regions where precipitation has decreased.

Hydrological relationships will affect living organisms directly by altered levels of precipitation, runoff, soil moisture, snow cover, snowmelt and evapotranspiration, as well as indirectly by transforming sea and lake levels, which influence coastal and shoreline ecosystems (Bardecki et al. 1990). The timing of water availability within ecosystems may also change. For example, earlier melting of snowpacks may mean that less water is available during summer. Higher-latitude regions are expected to experience more precipitation, particularly in the winter; in most cases this extends to mid-latitudes.

According to the Thornthwaite method, which is based on correlations between evapotranspiration and temperature in the current climate, some studies concluded that water may become more limiting with temperature increase in the future.

Impacts on forests and trees

Where climate change leads to annual or seasonal changes in water availability, forest productivity could change. Significant reductions in soil water availability could lead to forest decline. There could also be indirect problems, such as more floods and greater erosion hazards caused by more intense rainfall. Wind erosion could increase if drought lengthens the time that the ground is bare of vegetation.

Depending on rainfall or snowmelt intensities, as well as soil capillary and acquifer hydraulic conductivities, water will infiltrate and percolate into the soil. Soil water storage plays a decisive role in evaporation and evapotranspiration of plants. For a given soil depth and soil type, any change in the seasonal distribution of

precipitation or its intensities will change soil water storage, runoff processes, and groundwater recharge (Arnell et al. 1995).

All climate models show increased soil moisture in high-northern latitudes in winter, with reduction in some other area. Most models predict a drier surface in summer in northern mid-latitudes and a reduction in summer precipitation over southern Europe.

Changes in the ratio of precipitation to potential evapotranspiration could also affect water discharge into rivers and ground-water reservoirs.

2.5 OTHER CHANGES

The climate controls the location and distribution of tree species in the forest by shaping the two opposite forces that drive forest ecology: disturbance and succession.

Understanding the interaction of disturbance and succession gives clues about how forests might respond to climate change. Disturbance caused by fires, insects and storms largely determines the distribution of species within forests. The frequency of disturbance is closely linked to climate and can increase dramatically during warm, dry weather. The rate of succession can be significantly reduced by temperature, moisture or reproductive stress.

Warming in winter may allow destructive insects and pathogenic fungi to survive at higher latitudes than at present, enabling subtropical or warm-temperate pests and pathogens to invade vegetation from which they are now excluded (Dobson and Carper 1992). Some insects also will be able to complete more generations per year in warmer climates. Increased incidences of pests and diseases may further limit the growth of stands that are already declining for the effects of climate change or pollution.

Elevated CO_2 can change the palatability of leaves and either promote or discourage insect herbivorous (Overdieck et al. 1988; Mueller-Dombois 1992). In addition, where forests are defoliated or killed by drought, pests or pathogens, the risk of forest fires will increase and will extend the hazard to areas that are currently not affected.

3. EUROPEAN PROJECTS

This chapter provides on overview of the main, EU funded, ongoing research projects related to impacts of climate change on forests. For each of the project, a short introduction describes the aim of the project and, where possible, the estimated duration of the project. Moreover, for each project there is a list of the organisations involved in the research and for each of them the names of contact people. Because of the wide range of information it was not possible to fully describe each project but if more information are needed it is possible to find them on the web pages referred at the end of each project description in case such web page has been available.

1. FOREST RESPONSE TO ENVIRONMENTAL STRESS AT TIMBERLINES: SENSITIVITY OF NORTHERN, ALPINE AND MEDITERRANEAN FOREST LIMITS TO CLIMATE

Scope
A calibration data-set of climate/environment factors and a wide range of tree growth responses over the last 50-100 years will be produced along transects across the timberline in Northern Fennoscandia and on Alpine and Mediterranean mountains. The climate data will be obtained from both existing meteorological stations and on-transect monitoring sites. The present vegetation will be mapped in detail and the fertility of timberline species recorded. The three growth responses will include annual measurements of pollen and plant macro-fossil deposition, needle density and needle shed, stomatal density on needles, tree ring width, density, cell formation and structure and late-wood stable carbon isotope content. Focus will be primarily on *Pinus* but other tree species will be considered as regionally appropriate.

The multidata-set will be used to model the effect of climate on timberline forests by elucidating any significant effects of temperature, precipitation and CO_2 concentration on tree growth. This model will be tested on past situations of Holocene timberline and climate different from today namely 4000 years ago (Northern transects) and 8000 years ago (Alpine and Mediterranean transects) through determining the same tree growth response factors annually for these time windows. On the basis of this a predictive model of the responses of timberline forests to future changing climate will be built.

Duration: 01/Feb/1996 - 31/Jan/1999	
Prime Contractor:	University of Oulu, Department of Astronomy- Faculty of Science Contact person: Sheila Hicks, sheila.hicks@oulu.fi
Other Contractors:	Universität Bern – Geobotanisches Institut Contact person: Brigitta Ammann
	Aristotle University of Thessaloniki, School of Forestry and Natural Environment Contact person: Nikolaos Athanasiadis
	University of Wales, Swansea, Department of Geography Contact person: Danny Mc Carroll
	Universitetet I Bergen – Botanical Institute, Faculty of Mathematics and Exact Sciences Contact person: Hilary H. Birks
	Universität Hamburg – Ordinariat für Holzbiologie Contact person: Dieter Eckstein
	The Finnish Forest Research Institute, Rovaniemi research station Contact person: Risto Einar Jalkanen
	Université de Droit d'Economie et des Scienses d'Aix Marseille, Laboratoire de Botanique Historique et Palynologie Contact person: Jacques-Louis De Beaulieu
	University of Helsinki, Department of Geology, Faculty of Sciences Contact person: Hannu Hyvärinen
	Swiss Federal Institute for Forest, Snow and Landscape Contact person: Felix Kienast
	Universidade de Lisboa, Museu, Laboratório e Jardin Botanico Contact person: Fernando Mangas Catarino
	Leopold, Franzens, Universität Innsbruck, Institut für Botanik Contact person: Sigmar Bortenschlager
	University of Tromsø, Institute of Biology and Geology Contact person: Karl-Dag Vorren

2. PREDICTED IMPACTS OF RISING CARBON DIOXIDE AND TEMPERATURE ON FORESTS IN EUROPE AT STAND SCALE

Scope

The basic strategy is to focus on existing process-based, deterministic models at the scale of the stand. The models already available amongst the Partners involve overstorey, understorey, ground layer and soil, and include explicit formulations of physiological, developmental and growth processes at the scale at which impacts of CO_2 concentration and temperature have been demonstrated. These models will be compared one with another, improved, extended and rationalised with the aim of arriving at a consensus for making predictions of global impacts at stand scale. The models will be parameterised for particular forest stands in different climate and adaptive regions of Europe with parameters obtained in earlier EU supported programs, obtained during this project by the group of Partners, and obtained in parallel projects elsewhere.

The models will be validated at stand scale by comparisons between the predicted fluxes of CO_2 and water vapour and fluxes measured in a parallel project (EUROFLUX) in the current ambient climate at several sites in different parts of Europe. They will also be validated in future climates by comparison between model predictions of fluxes and growth and measurements made in mini-stands and ecosystems where model forests are grown in both ambient and elevated CO_2 concentration.

The validated models will be applied to selected stands of trees in different parts of Europe for which appropriate parameterisations are possible, and predictions made of the likely impact of global environmental change on the functions and yield of the stand. For this goal, the climate variables will be regarded as independent driving variables. Forest-soil interactions will also be scaled up in time by taking account of changes in slowly varying pools of soil organic matter over time periods of 100 years during which a doubling of the atmospheric CO_2 concentration is likely to occur.

Duration: 01/Feb/1996 - 31/Jan/1999	
Prime contractor:	University of Edinburgh, Institute of Ecology and resource Management Contact person: Paul Jarvis, p.jarvis@ed.ac.uk
Other contractors:	Faculté des Scienses Agronomiques de Gembloux, Unité d'Enseignement et de Recherche Biologie Végétale Contact person: Eric Laitat
	Universitaire Instelling Antwerpen, Laboratorium voor Plantecologie, Departement Biologie Contact person: Reinhart Ceulemans
	Université de Paris-Sud XI, Laboratoire d'Ecophysiologie Végétale Contact person: Bernard Saugier
	The Swedish University of Agricultural Sciences, Department of Ecology and Environmental Research Contact person: Sune Linder
	University of New South Wales, School of Biological Sciences Contact person: Ross Edward Mc Murtrie
	Technische Universität Berlin, Ökologie der Gehölze Contact person: Dieter Overdieck
	Institute of Landscape Ecology, Czech Academy of Sciences, Department of Ecological Physiology of Forest Trees Contact person: Michal Marek
	University of Joensuu, Faculty of Forestry Contact person: Seppo Kellomäki
	Forestry Commission, Research Division (UK) Contact person: Peter Hamilton Freer-Smith
	Natural Environment Research Council, Institute of Terrestrial Ecology Contact person: Maureen Brigette MURRAY
	Universitá degli Studi della Tuscia, Dipartimento di Scienze dell'Ambiente Forestale e delle sue Risorse Contact person: Giuseppe Scarascia Mugnozza

3. A EUROPEAN PROGRAMME ON PREDICTION OF CLIMATE VARIATIONS ON SEASONAL AND INTERANNUAL TIMESCALES.

Scope

The first objective is being pursued through a series of co-ordinated experiments using four European atmosphere models. These models are being run in ensemble mode over seasonal timescales using observed sea surface temperature and initial conditions from the ECMWF reanalysis period 1979-1994. This co-ordinated experimentation was underway at the beginning of the project, and is likely to be completed by the end of the first year. Diagnosis of results will take another year, and involves additional participants in the project.

Complex numerical coupled models and ocean data assimilation techniques are being developed by five participants of the projects, and the ability to run hindcast experimentation will be possible by the second year of the project.

Testing the skill of the numerical coupled model seasonal forecasts will begin in the second year of the project, through co-ordinated experimentation. Special attention will be given to the period 1990 onwards, since the ocean (especially the El Niño region), was relatively well observed in that period.

The skill of dynamically based seasonal forecasts will be compared with that obtainable by empirical prediction techniques. In addition the possibility of using these techniques (e.g. based on singular value decomposition) to correct, a posteriori, dynamical model biases will be investigated.

Finally, close co-ordination between PROVOST and the monsoon project SHIVA will take place throughout the term of the project. As well as undertaking joint numerical experimentation, the SHIVA and PROVOST project will meet jointly each year.

Duration: 01/Mar/1996 - 28/Feb/1999 More information: http://apollo.cordis.lu/cordis-cgi/srchidadb?ACTION=D&SESSION=105641998-7-15&DOC=7	
Prime contractor:	European Centre for Medium-Range Weather Forecasts Contact person: Timothy Noel Palmer
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4. EUROFLUX: LONG TERM CARBON DIOXIDE AND WATER VAPOUR FLUXES OF EUROPEAN FORESTS AND INTERACTIONS WITH THE CLIMATE SYSTEM

Scope
EUROFLUX programme will address the following specific objectives:

- To characterise fluxes and energy exchange at the surface in order to provide useful parameters to global and regional climate modellers and to analyse the variables that determine energy partitioning by forests in different climatic conditions, including extreme events and stress limitations.
- To determine the sink strength of European forests for carbon and analyse the variables that determine the gains and the losses of carbon from forests of differing vegetation composition and in different climate regions.
- To analyse the response of water and carbon fluxes from European forest to climatic factors in order to aid regional scale modelling designed to predict impacts of global environmental change on forest ecosystem function.
- To provide information for the development and testing of schemes designed to elaborate forest-atmosphere interactions based on remotely sensed data.
- To recommend management strategies for the conservation of carbon stores in forests.

The study of the interactions between forests and atmosphere has recently been made more routine by new developments in the eddy covariance technique. Within EUROFLUX, eddy covariance will be used for long term continuous measurements of mass and energy fluxes, to capture seasonal dynamics and allow foor a meaningful scaling with respect to time. Indeed, many of the processes driving water and carbon fluxes at ecosystem level are strongly dependent on seasonal changes in climate. Seasonal changes of phenology and biomass production affect significantly the rates and properties of water and carbon exchanges in the atmosphere. Furthermore, extreme events (temperature, high wind velocity, drought conditions) are not often considered during short term field campaigns but can have a strong impact on the hydrological and carbon cycles.

Within EUROFLUX the equipment and methodology is standardised using a common software and instrumentation design in order to have a solid basis for site intercomparison. This project combine flux measurements on a continuous multi-year time basis with ecological process interpretation and modelling. Long-term measurements of the fluxes of CO_2, water vapour and energy exchange re carried out at 15 representative forest sites encompassing the entire range in European climate, species distribution and site conditions. The selected sites are representative of the regional features of the European basin (Mediterranean, Boreal, Continental, Atlantic) and form a unique integrated system for the analysis of climate-related ecosystem processes, their impact on hydrological and carbon cycles and will represent test cases for validation of environmental policies.

Within the project EUROFLUX some main topics are developed:

- Eddy covariance measurements of CO_2, H_2O and energy exchanges
- All the sites will be equipped with a standard equipment for eddy covariance measurements of carbon dioxide, water vapour, sensible heat and momentum fluxes.
- In each of the study sites energy balance determination will be carried out.

Validation of flux measurements and analysis of turbulence
Two independent tests will be carried out to check the validity of eddy flux data: energy balance closure and spectral analysis. In addition a boundary layer analysis will be conducted during night time conditions, to check the response of the eddy covariance system under high atmospheric stability.

Air isotopic concentration and fluxes
Short campaigns will be carried out in order to provide measurements of carbon and oxygen isotopic composition of the air within and above the canopy on a seasonal basis to determine isotopic fluxes. For the determination of isotopic fluxes, two techniques will be used, concentration gradient and eddy accumulation.

Components of carbon balance
In order to provide basic information on the carbon distribution within the ecosystem and its changing in time, measurements of biomass components (leaf area index, wood increment and root biomass) will be carried out in all the sites.

Biomass and soil respiration
Soil carbon dioxide fluxes will be estimated by cuvette measurements. Intercomparison exercises are planned in order to evaluate the system performances of each group and to provide a common background for soil respiration measurements. Soil temperatures and soil moistures will be measured in parallel in order to provide functional relationships between climatic factors and fluxes.

Distribution of resources at soil and canopy level
Light interception of the canopy will be measured along the season at different depths. Measurements will be also conducted on leaf level photosynthetic characteristics, leaves nutrient distribution and isotopic composition along a vertical gradient within the canopy. Soil nutrients will be investigated to provide a basic information of the fertility and production potentials of the sites.

Components of the hydrological balance
Water inputs will be measured by rainfall gauges and in some sites it will be possible to measure throughfall and stemflow along the season. Soil moisture changes will be followed during the season at each site with a combination of different techniques (soil tensiometers, neutron probe and time domain refractometry).

Tree level transpiration studies
Tree transpiration will be measured. In addition, tree crown conductances will be calculated by sap flow and water potential gradients. The crown conductances will then scaled up at canopy level and compared with canopy conductances determined by eddy fluxes.

Validation of SVAT models
Already existing models will be parametrized for a number of sites in order to achieve the following objectives :
1. develop a tool for filling gaps in the long term data series
2. validate model outputs with real flux data.
In particular the following SVAT models will be used: MAESTRO, CANOAK, GAS-FLUX and STANDFLUX.

Data base structure and management
During the experimental activity a flow of data will be established between the participating teams in order to create a common data base. At the end of the project a unique set of data of continuous fluxes of various European forests will be available to the external community.

Duration: 01/Feb/1996 - 31/Jan/1999 More information: http://unitus.it/eflux/what.html	
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5. ECOMONT: Ecological Effects of Land-Use Changes on European Terrestrial Mountain Ecosystem

Scope
The aims of the ECOMONT project are:

• to investigate which changes in the canopy structure occur due to land-use changes in agricultural and forestal Alpine ecosystems along a South/North research-transect across the Eastern Alps and how these changes affect the exchange processes with the atmosphere;
• to clear up how the changes in canopy structure are connected with species composition and performance, as well as with species competition and interaction;
• to understand the influence of land-use changes on soil organic matter (SOM) status and turnover, on biogeochemical (CO_2, N) and hydrological processes at the ecosystem level, and on the exchange processes between the ecosystems and the lower layers of the atmosphere;
• to extend this understanding to the landscape level by means of multimedia modelling activities;
• to compare the results from the Alps with those of other European Mountains (Spanish Pyrenees, Scottish Highlands);
• to develop functional analysis methods as a basis for the integrated management (sustainable development) of mountain ecosystems.

The three pilot research areas "Monte Bondone", "Passeier Valley" and "Stubai Valley" in the Italian and Austrian Alps give the unique possibility of investigating the connections between land-use changes and the transport of sensible heat, latent heat (water vapour), CO_2 and pollutants (combing effects of different canopy structures) across the Alps. As the research area on Monte Bondone was investigated in detail within the EC-STEP project INTEGRALP (Cernusca & al. 1992), results of INTEGRALP can serve as an important baseline for ECOMONT.

The main topics of this project will be:

Spatial distribution of vegetation and soils in the experimental sites
The large-scale mapping of vegetation and soils will be the basis for scaling up the results of the detailed ecosystem analyses to the landscape level. Furthermore the maps will serve for calibrating and verifying the remote sensing data.

Physical and chemical soil properties
- Determination of soil physical parameters (pore size distribution, bulk density, contents of clay and organic carbon). These parameters will be used for modelling of the soil water balance.
- Measurements of SOM status and turnover, and of plant available nutrients in the soil.

Canopy structure, primary production, decomposition
- Canopy structure will be analysed by indirect methods (hemispherical lens measurements) and by direct methods (stratified clipping and hand inclinometer).
- Primary production will be analysed using the harvesting method. This involves measurements of biomass, necromass and litter throughout the year.
- Litter decomposition will be investigated by the litter bag technique.

Water relations and hydrological balance of ecosystems, catchments
- Precipitation amount and intensity will be measured using a tipping bucket raingauge,
- Soil water content and soil water potential will bedetermined simultaneously and will allow an in-situ description of the characteristic water content - potential curves; for quality assurance this curve will also be determined by laboratory methods on soil cores.
- Evapotranspiration of grassland and dwarf shrub ecosystems will be monitored by lysimeters, as well as by the energy-balance-Bowen-ratio-method.
- Run-off from defined experimental plots will be monitored by means of a seesaw system.

Microclimate, energy budget of ecosystems
Portable battery-powered data acquisition systems will be installed during the main growth period at each investigation site.

Gas exchange (CO_2, H_2O, and related trace gases) of single plants, and ecosystems

Gas exchange (CO_2, H_2O, and related trace gases) between the experimental sites and the adjacent atmosphere

Population and plant biological studies
The studies aim at assessing the effects of changes in resource availability (light, nutrients, CO_2, water) and mechanical impacts (grazing, mowing) on the form and functioning of plant species and their populations. The methods to be applied are from the field of ecophysiology and population biology.

Potential risks through land-use changes

- Key parameters of soil stability: At the beginning of the investigations soil-mechanical parameters of the sloped sites will be analysed. Together with water content and pore water pressure, these parameters give an estimate of soil stability.
- Determination of rooting density and rooting intensity on slopes will be carried especially during late summer when events of heavy rain and storm are most likely to occur.
- Development of patches of bare soil and unstable slopes.
- Development of snow gliding avalanches.

Geographic Information System (GIS)
The registration of data in a Geographic Information System makes possible a functional superimposition of the maps and the other spatially relevant data. The data of all investigation areas will be digitalized with Arc-Info, read in, edited and processed. The data will be visualised, analysed and organised with the data Publishing-Programme Arc-View. This form of data recording and processing guarantees the possibility of using and transferring the data between the individual partner teams of ECOMONT.

Remote Sensing - environmental mapping
Remote sensing will be carried out at up to four sites using an aircraft-mounted multi-spectral imaging system with a 4 metre pixel size, and will cover an area of about 140 square kilometres.

Integrative modelling activities
A hierarchy of models scaling up from the individual leaf or branch to the stand and the landscape (catchment) will be used to quantify controls on CO_2 and water fluxes within the Alpine ecosystems and landscapes (watersheds).

- Leaf and Branch Gas Exchange
- Canopy Gas Exchange
- Landscape Gas Exchange

Duration: 1996-1998 More information: http://info.uibk.ac.at/c/c7/c717/ecomont/	
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6. WISE: WEATHER IMPACTS ON NATURAL SOCIAL AND ECONOMIC SYSTEM

Scope

The aim of this research project is to perform empirical studies of the impacts of climatic variability, in particular hot summers, warm winters and wind storms, natural, social and economic system in Europe.

Most studies of potential economic impacts of climate change draw upon scenarios of future climate and of the future economy. Another approach, which has been pursued only recently, is to consider observed impacts of recent climate extremes on economies and societies. Although no direct comparisons can be made between the impacts of climate variability and of climate change, empirical studies of recent climate extremes can provide useful information about the nature and scale of impacts on different sectors and upon the way in which different cultures respond.

The impacts of a recent hot summer, warm winter and a wind storm on the economies, societies and natural environments of four European countries (the UK, the Netherlands, Italy and Germany) are to be studied primarily through quantitative analysis of published statistics. A sector-wise approach is to be taken, with a core group of sectors amongst the participants in order to allow international comparison. Where possible, a monetary value will be placed on the impacts. In order to assess possible time-dependent changes in the sensitivities of systems to climate extremes, a comparison with the impact of an earlier event will be carried out for each type of extreme (for example, a comparison of the impacts of the 1995 and 1976 summers). In addition, transnational impacts will be examined through case studies of perturbations in international tourism and the flows of agricultural produce in response to climate extremes.

Perceptions of the impacts of climate variability, both among the general public and among policy makers and management, will be examined by questionnaire and interview. Identification of the extent to which adaptations are already occurring in response to a perceived increase in certain types of extreme forms an important component of this research. This in turn should shed light on the extent to which an increased frequency and/or severity of climate extremes in the future can be accommodated at the institutional level without costly intervention at the national or international level.

At the close of the project, a workshop will be held with participants from public, private and non-governmental environmental organisations to discuss the wider implications of the project. Results and analyses of the main findings on national differences and similarities in impacts, adaptations and sensitivities to climate extremes and shocks, and their possible causes, will be covered in the final report.

<table>
<tr><td colspan="2">Duration: 01/Nov/1997 - 31/Oct/1999</td></tr>
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</table>

7. LONG-TERM REGIONAL EFFECTS OF CLIMATE CHANGE ON EUROPEAN FORESTS: IMPACT ASSESSMENT AND CONSEQUENCES FOR CARBON BUDGET (LTEEF-II)

Scope

Forests are especially vulnerable to climate change, due to the longevity of trees and the expected climate change within their life-span. The central objective of the LTEEF-II project is to assess climate change impacts on European forests with respect to water and carbon fluxes, regional differences, long-term effects, and the overall carbon budget for forests in Europe.

This will be done by:

- assessment and process-based modelling of the long-term regional impacts of climate change on Europen forests,
- upscaling of such regional responses to the European scale by both forest inventory data and remote sensing data.

The results will include:

- assessment of likely responses of forest to climate change in the main regions in Europe;
- quantification of changes in fluxes of carbon and water between vegetation and the atmosphere, in both timing and magnitude;
- assessment of possibilities of acclimation by means of self-regulating processes of existing forest;
- identification of response strategies for forest management;
- assessment of the carbon balance for the forest sector.

The consortium proposing the project consists of 14 groups working throughout Europe within the field of : mechanistic modelling of forest growth; analysing growth and yield based on forest inventories (large scale forestry model); GIS and remote sensing.

This project builds upon a recently finished European project (LTEEF, 1994-1996) in which the potential for existing forest stands to acclimate to changing climatic conditions was analysed.

Duration: 01/Jan/1998 - 30/Jun/2000 More information: http://www.ibn.dlo.nl/LTEEF-II/	
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8. EUROPEAN COLLABORATION ON CO_2 RESPONSES APPLIED TO FORESTS AND TREES (ECOCRAFT)

Scope
This project is primarily concerned with the impacts of rising carbon dioxide concentration and temperature on the growth processes of trees, and additionally with the use of models to upscale the responses of the processes to the scale of forests over tens of years and flux measurements to test the models.
The specific objectives are the following:

(a) To define and describe those growth processes in trees that are affected by the rise in atmospheric CO_2 and by the increase in temperature. Through a programme of experiments, to express the responses of these processes explicitly, and to derive the parameters for the expressions, for the use in models.
(b) To develop process-based models that include explicit representation of biochemical and physiological processes affected by the rising atmospheric CO_2 concentration and temperature for the purposes of up-scaling the responses to the spatial scale of the stand and the temporal scale of tens of years.
(c) To test the models against flux measurements made by eddy covariance measuring systems and to use the models to make predictions of the likely consequences of global change at larger scales.

The project comprises 12 participants drawn from nine countries. The present project was expanded by inclusion of two Participants in the boreal forest region of northern Europe, in northern Sweden and eastern Finland and eastwards through the "Central and Eastern European Programme 1992" by the inclusion of Participants in the Czech Republic. Finally, a fully equipped open top chamber site was brought into the project in central Scotland by an additional sub-contractor in the UK.

The geographical range of the project was from 63° 50' in the north to 42° 25' in the south and from the 29° 46' in the east to 3° 13' in the west. There were three Participants (plus three sub-contractors) in Northern Europe, in the UK, Sweden and Finland; four Participants in Central Europe in Belgium, Germany and France; a Participant in East Europe in the Czech Republic; and one Participant in Southern Europe in Italy.

Duration: 1/Jan/1996 - 1/Jan/1998	
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9. FOREST MODELLING ASSESSMENT AND TREE-RINGS (FORMAT)

Scope

The aim of the project is to assess the sensitivity of tree-growth to climate change in mountain and Mediterranean forests, both in its past variability and in the future as predicted by climate models for a CO_2 doubling scenario. This will provide a basis for assessing environmental and socio-economic impact of different tree-growth scenarios and for allowing the development of strategies for sustainability in future forest management.

The preliminary issue of the whole approach deals with the collection and the gathering in a data base of both tree-ring and meteorological data. On the whole area, the tree-ring data set must cover a grid dense enough to overlay the spatial variability of climate and forest environment, including man-induced variability. The meteorological data set will be defined in order to represent at best the regional climate prevailing in the forest sites sampled. For tree-ring data, time resolution is the year, while monthly and, when possible, daily values are needed for meteorological data.

The main effort will be focused on the last century for which data sampling strategy will be developed on three target areas in order to obtain a data set representative of the main conifer forests of southern Europe, from West (Spain) to East (Italy).

Spatio temporal tree-growth variability will be analysed on the longest time span possible (back to 900 AD), both in the scope of normal variability and extreme events. Signal analysis of tree-ring chronologies will be performed in order to separate climatic signal from other signals much more linked to human activities and to assess actual and future variability on the longest time period.

Statistical models of tree-ring to climate relationships (response function), using meteorological data, will be elaborated for each tree population. Due to availability of meteorological data, this calibration will be done, at best, over the period 1900-1995.

Responses of tree-growth to climate models previously established will be used to predict the growth response of each tree-population to a climate change as predicted by a CO_2 doubling scenario (based on the regionalised output of GCM simulations transferred to the meteorological station used in the calibration of response function). This predicted effect will be compared to the past natural variability, both of climate and tree ring series.

In order to obtain a global representation of coniferous forest diversity, core sampling and modelled growth will be mapped at the forest level using remote sensing and GIS techniques.

More information: http://medias.meteo.fr/format	
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10. ARCTIC-ALPINE TERRESTRIAL ECOSYSTEM RESEARCH INITIATIVE (ARTERI)

Scope

This project is a 3-year Concerted Action programme (1996-98) launched by the EC as a component of the Terrestrial Ecosystem Research Initiative (TERI), focusing on the interactive effects of changes in land-use, climate, and composition on arctic and alpine terrestrial ecosystems.

The Objectives of ARTERI were:

•To provide a forum for exchange of information and development of collaboration in European Arctic and Alpine terrestrial research.
•To develop a theoretical and practical framework for inte-gration of the research effort
•To provide a focus for European collaboration with other regional and global research.
•To identify priorities and proposal for further research, integration and interpretation

Duration: 1996 – 1998 More information: http://www.dpc.dk/Arteri.html	
Organisations involved	Danish Polar Center Contact person: Thomas Bjørneboe Berg, tbb@dpc.dk
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	The University of Edinburgh, School of Agriculture, Institute of Ecology & Resource Management Contact person: Bill Heal, vis001@ed.sac.ac.uk
	Arctic Centre University of Lapland Contact person: Hukkinen Janne, jhukkine@levi.urova.fi
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11. ANALYSIS OF DENDROCHRONOLOGICAL VARIABILITY AND ASSOCIATED NATURAL CLIMATES IN EURASIA - THE LAST 10.000 YEARS (ADVANCE - 10K)

Scope

This project is focused in the area of dendroclimatology. The absolute dating control and seasonal growth of long tree-ring chronologies will be used to reconstruct a range of climate variables in different regions of northern Eurasia to enhance our knowledge of natural climate variability on a range of timescales within the last 10,000 years and advance our understanding of the mechanisms and forcings that have generated this variability.

The project encompasses extensive development of new densitometric chronologies in northern Siberia, part of ongoing work funded largely by The Swiss National Science Foundation. In addition, the major collections of European historical and sub-fossil oak ring-width data, principally from Great Britain, Sweden, Holland, Denmark, Germany and Poland, are being centralised, quality-controlled and entered into a common European tree-ring data base. Some modern chronology development is being undertaken to update these data and provide modern analogues for comparison with recent climate data.

The project will reconstruct changes in temperature and precipitation-related variables over a range of temporal and spatial scales determined by the length, location and climate sensitivity of the available tree-ring data. This work will generate detailed individual maps of summer temperatures over several centuries across northern Siberia. These data will be interpreted in terms of large-scale atmospheric circulation patterns over western Europe and northern Eurasia and within the context of the large-scale general circulation of the Northern Hemisphere. Tree- growth and derived climate variability will be compared with (less-well-resolved) independent evidence of climate change in, and outside of, Europe, and with proxies of potential climate forcings such as volcanic, solar and Milankovitch changes throughout the Holocene. We will also explore evidence for the influence of ocean dynamics on European climates by comparing the statistical characteristics of our reconstructions with those of climate data produced by appropriate fully-coupled Ocean/Atmosphere General Circulation Models.

Continuous regional-average timeseries will be produced spanning several millennia in specific regions of Sweden, Finland and Central Europe. These will allow an exploration of the evidence for contemporaneous, widespread and abrupt tree-growth changes that may indicate the effects of major environmental disruption potentially due to volcanic or cometary activity.

Duration: 1996 – 1998 More information: http://www.cru.uea.ac.uk/advance10k/workprog.htm	
Organisations involved	University of East Anglia, Climatic Research Unit Contact person: Dr Keith R Briffa, Project co-ordinator, k.briffa@uea.ac.uk
	Queen's University, School of Geosciences, Palaeoecology Centre Contact person: Prof. M.G.L. Baillie, m.baillie@queens-belfast.ac.uk
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	University of Helsinki, Department of Geology Contact person: Professor M. Eronen
	University of Stockholm, Department of Physical Geography Contact person: Professor W. Karlén Mr H. Grudd, grudd@natgeo.se
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	Universität Hohenheim, Institut für Botanik Contact person: Professor B. Frenzel
	Forstliche Biometrie Institut Institut für Forstgenetik und Forstpflanzenzuechtung, Forstliche Biometrie und Informatik Contact person: Dr T. Riemer, triemer@ufobi2.uni-forst.gwdg.de

	Forest Research Institute, Rovaniemi Forest Research Station Contact person: Mr M. Timonen, mauri.timonen@metla.fi
	University of Joensuu, Karelian Institute, Section of Ecology Contact person: Mr P. Zetterberg, zetterberg@joyl.joensuu.fi
	Ural Branch of the Russian Academy of Sciences, Institute of Plant and Animal Ecology Contact person: Professor S. Shiyatov
	Institute of Forest, Akagemgorodok (Russia) Contact person: Professor E.A. Vaganov

4. NATIONAL PROJECTS

This chapter provides information about ongoing projects on impacts of climate change on forests in several European countries. The kind of information given is the same that in chapter 3 and also some indications about laboratories involved in this kind of research are included.

BELGIUM

1. Global Change and Sustainable Development

Scope
The two general objectives of this project are to:

1) reduce uncertainties about the extent and patterns of global environmental problems, through a better understanding of the ecosystem and its interaction with socio-economic systems, to provide a firmer scientific basis for decision-making;
2) help strengthen the scientific and technical basis needed to make (federal, European and international) and implement (federal and regional) policy on Global Change and Sustainable Development, with particular reference to climate change.

Within the previous two there are some scientific objectives like:

1) to understand the physical, chemical and biological processes of change in the Earth System and their interactions, particularly those implicated in climate change, stratospheric ozone change in the mid-latitudes, the oxidative capacity of the atmosphere (including tropospheric ozone creation) with particular attention to human-induced changes.
2) to develop methods and models to explain the operation and evolution of the climate system, its influences, and to project potential climate changes (nature, magnitude, timing).
3) to understand the effects of Global Change and especially the effects of climate change on terrestrial ecosystems, hydrological cycles, essentially in Belgium, including a risk or "vulnerability" assessment; The results must be compiled and globalized in a report relevant to Belgium;
4) to develop tools (models, methods,...) with which to evaluate the consequences of policy options.

The expertise developed must support Belgian international policy-making, and the national communications which Belgium is required to make under the Climate Convention, the European Council Decision for a monitoring mechanism of CO_2 and other greenhouse gas emissions, and in the framework of the CSD (Council for Sustainable Development).

Duration: 01/Dec/1996 - 30/Nov/2000 More information: http://bartok.belspo.be/fedra/asp/prog_uk.asp?COD=CG	
Responsible organisation:	Federal Office for Scientific, Technical and Cultural Affairs Contact person: M. Vanderstreten, vdst@belspo.be Van der Werf, vdwe@belspo.be Germain, germ@belspo.be

2. The carbon cycle and the future level of atmospheric CO_2

Scope
Carbon dioxide is the main greenhouse gas directly controlled by human activity and it is expected to remain so in the future. Combustion of fossil fuels and land use changes release about 7 Gigatons of carbon into the atmosphere every year. Today, approximately 50% of the released CO_2 remains in the atmosphere and contributes to a global warming. However, small changes of the exchange fluxes between the main active carbon pools (atmosphere, ocean, biosphere) may modify this fraction in the future. Therefore, the complexity and non-linearity of the Earth system make it necessary to build coupled numerical models of the global carbon cycle to predict quantitatively future atmospheric CO_2 levels.

The objective of the project is to develop an integrated model of the Global Change cycle and to use it to calculate the evolution of the CO_2 accumulation in the atmosphere during the next decades based on socio-

economic scenarios. This coupled model will be based on tools and expertise of the three participating teams. The ocean carbon module will be based on the existing model at LPAP (University of Liege) which will be improved to include consideration of coastal biogeochemical cycles, a field of expertise of the Free University of Brussels. The role of the biosphere (including soil carbon) as a sink or source of carbon will be described using a future time-dependent version of the CARAIB model. Particular attention will be given to the validation of the calculated biospheric productivity and net ecosystem productivity .

The seasonal and interannual CO_2 concentration will be calculated using a 3-dimensional atmospheric transport model and compared to the signal measured at various stations. Satellite remote sensing will also provide a global validation method. For this purpose, the Center for Teledetection and Atmospheric Processes of VITO will provide its expertise in vegetation remote sensing to use the AVHRR/NOAA sensor data for validation and data assimilation in the model.

At the end of this project, a global carbon cycle model will be available. Simulations predicting the level of atmospheric CO_2 will be made for various socio-economic scenarios.

Duration: 01/Dec/1996 - 30/Nov/2000	
Organisations involved	Université libre de Bruxelles, Laboratoire d'Océanographie Chimique Contact person: Prof. R. Wollast, rwollast@ulb.ac.be
	Université de Liège, Institut d'Astrophysique, Lab. De Physique Atmosphérique et Planetaire Contact person: Prof.J.C. Gerard, gerard@astro.ulg.ac.be
	Flemish Institute for Technological Research Contact person: Dr. F. Veroustraete, veroustf@vito.be

3. Modelling the climate and its evolution at the global and regional scales (CLIMOD network)

Scope

The main objective of the CLIMOD (CLImate MODelling) network project is to contribute to the international research effort leading to an improved understanding of the climate system and to a better assessment of the impact of human activities on the global and regional climates. Two main tools will serve this objective: modelling and data analysis.

Today, members of the CLIMOD network have at their disposal a coupled atmosphere-ocean general circulation model (AOGCM; the first and only one in Belgium), a regional atmospheric model (RegAM), and a Greenland ice-sheet model (GISM). Each of these complex three-dimensional models is run by a different team in a different location. At the end of the project, an advanced "community model", to which each team will have contributed a component will be accessible to all in a common computer environment.

The physics in each component will be improved to stay in line with the latest advances of the climate science. Interactions between turbulence, convection, clouds, and radiation will receive particular attention in the AOGCM, with the specific goal to reduce the drift observed with most similar models. The GISM will be improved in the areas of basal sliding, iceberg calving, and bedrock isostasy. After a thorough validation over Greenland, the RegAM will be used to develop a meltwater-budget parameterization to be imbedded in the coupling interface between the GISM and the AOGCM. A 50-km resolution version of the RegAM will be validated over Western Europe for the present climate. In a finer-resolution version of the RegAM limited to Belgium, one will test physical parameterizations adapted to the simulation of extreme weather events (e.g., storms, fog). To validate these models and put the future regional changes they simulate in perspective, data from two sources will be used: analyses from a numerical weather prediction model, and a new regional database for Belgium produced for this purpose.

The AOGCM and GISM will be coupled using the parameterization derived with the RegAM. The coupled model will then be forced with the IPCC IS92a scenario, and the impact of iceberg discharge and meltwater flow on the sea level and on the oceanic thermohaline circulation will be studied. The results of this coupled run will be analysed, with a particular attention paid to Western Europe and the North Atlantic.

To refine climate projections over Western Europe, the 50-km resolution RegAM will be nested in the coupled model, and time-slice climate change experiments will be performed. Finally, the transition towards an even more advanced AOGCM will be prepared.

Duration: 01/Dec/1996 - 30/Nov/2000	
Organisations involved	Vrije Universiteit Brussel, Geografisch Instituut Contact person: Prof. H. Decleir, hdecleir@vnet.vub.ac.be Dr. P. Huybrechts, phuybrec@vub.ac.be
	Université Catholique de Louvain, Inst. d'Astronomie et de Géophys Contact person: Dr. T. Fichefet, Fichefet@astr.ucl.ac.be Dr. H. Gallee, Gall@astr.ucl.ac.be Prof. J.P. Van Ypersele de Strihou vanypersele@astr.ucl.ac.be
	Institut Royal Météorologique de Belgique, Section de Climatologie Générale Contact person: Dr. C. Tricot, clim@oma.be

4. Effects of the increase in the atmospheric CO_2 concentration on the primary production and the distribution of carbon in typically Belgian forest ecosystems.

Scope
The goal of the project is to study the effect of greenhouse on the clear CO_2 assimilation, the growth and the clear primary productivity of the forest ecosystems with null and void sheets and semper transfer. The effect of greenhouse is defined in this study like the redoubling of the atmospheric CO_2 rate, C-with-D up to 700 PPM.

The project envisages a strategy of search made up of three different phases:

1. Fundamental analysis of the effect of greenhouse on the basis of measurements of photosynthesis and growth in a greenhouse enriched by CO_2 and a not enriched greenhouse (used thereafter like "model system").

2. Similar collection of information under real forest conditions, by carrying out measurements of photosynthesis, growth and biomass within 3 typical Belgian forest ecosystems, namely the wood " Aelmoeseneie " (which is in fact a laboratory) of Faculteit Landbouwwetenschappen of the university of Ghent located at Gontrode, a homogeneous whole of woodland pines with Hechtel and a homogeneous whole of poplars also forming part of wood " Aelmoeseneie ".

The comparison of the results of measurement carried out, clear remains on the model system with the results resulting from real forest situations in order to extrapolate the effects of increased a CO_2 rate observed in the model system towards the level of the primary productivity within typically Belgian forest ecosystems. Thus will try one to establish forecasts scientifically justified as for the evolution of the productivity and the carbon cycle in the future, when the atmospheric CO_2 rate inevitably doubles in the middle of the next century.

Duration: 01/Dec/1990 - 31/Oct/1994	
Promoter:	Universiteit Gent, Laboratorium voor Plantecologie Contact person: Prof. R. Lemeur, Raoul.Lemeur@rug.ac.be

5. Effects of the increase in the concentration of atmospheric CO_2 and the temperature of the air on the ecosystems of meadow.

Scope
The aims of this project can be divided into four different groups:

A. Study on stimulations of ecosystems of meadows, long-term interaction between:

(1) a doubling of the atmospheric CO_2 concentration
(2) a rise of the temperature at the time of the growth of the vegetation
(3) of the water and nitrogen assessments

B. Enlarging of the scale and extension towards other types of vegetation by the means of remote sensing.

(1) Determination of the growth of the biomass during the season of growth as regards the types of natural " and agricultural vegetation " on the Belgian territory. The classification of these types of vegetation is the same one as that used within the framework of program CORINE of the EC.
(2) Definition of the correlation biomass-dioxide of carbon-capacity of fixing for the selected types of vegetation, leading finally to the estimate and the cartography of the capacity of fixing out of carbon dioxide for the Belgian territory.

C. Study of the action independent and synergic of an increased atmospheric CO_2 concentration, of a change of temperature and a manure by nitrogen on the competition enters the various kinds of meadows as functional types.

Formulation of the agronomic and phytotechnic implications general of a concentration increased out of CO_2 and temperature (for example as regards the manure, the selection, the management of mowing, etc).

Duration: 01/Dec/1990 - 30/Nov/1994	
Organisations involved	Universiteit Gent, Laboratorium voor Plantenteelt Contact person:Prof. T. Behaeghe
	Universitaire Instelling Antwerpen, Laboratorium voor Plantecologie Contact person: Prof. I. Impens, pleco@uia.ua.ac.be
	Flemish Institute for Technological Research Contact person: Dr. J.Kretzschmar, kretzscj@vito.be

6. Hydrological, soil chemical and ecological effects of climate change in species rich fens

Scope

Rich fens are amongst the most species rich herbaceous vegetation types in Europe. Their vegetation is characterised by low growing, evergreen species. Given the right environmental conditions (predominantly determined by soil chemistry and hydrology), and very extensive management, they exhibit stable coexistence of numerous species of which none reaches dominance. They are therefore excellent model systems to study in the framework of this programme:

1. they contribute enormously to biodiversity when their small size is taken into account,
2. their precious environmental status is a good indicator for the biodiversity success of sustainable development and
3. there is a need for studies of complex systems reaction to global change, including species interactions and soil process feedback's.

This project we will not adopt this echo-physiological approach, but we will rather concentrate on hydrological and soil chemical effects of climate change. In wetlands, hydrology is the primary factor shaping the ecosystems appearance. This is especially true for the systems under study: their base richness, low productivity and permanent wetness all result from their hydrological status and relations with the surroundings. In previous research we demonstrated that the soil chemistry of rich-fens may be much more dynamic then previously thought. Lowering the water table after summer drought immediately initiates an acidification process in the fen soil and may lead to higher phosphorus (P) concentrations in soil water. The present proposal is a follow up to this project and will work towards applicability of the knowledge in methods for sustainable policy development with respect to biodiversity and global change. It will concentrate on three issues:

1. the construction of a general model of fen soil sensitivity to drought induced acidification, taking into account soil physical and chemical aspects, and the site specific relation of the water table movement with the climate. Models of the relation between hydrological status and climate will be based on climate data which are available through RMI. Future climate scenario's will be selected in co-operation with climate groups in the program (UCL, RMI). If climate scenario's of sufficient resolution are not available historical data-series of extreme events will be used;
2. model the behaviour of P in rich fen soils under ‘normal' and transient conditions of drought and acidification; and
3. assess, through the use of micro-cosm experiments, the response of different functional groups in the vegetation to drought induced acidification and estimate the P availability to the vegetation in ‘normal' and transient conditions.

The study sites will be based in Belgium, but surveys will be conducted abroad to extend the data basis of the project.

Duration: 01/Jan/1997 - 30/Nov/2000	
Organisation involved	Katholieke Universiteit Leuven, Laboratorium voor Bodemvruchtbaarheid en Bodembiologie Contact person: Prof. K. Vlassak, Karel.Vlassak@agr.kuleuven.ac.be
	Universitaire Instelling Antwerpen, Departement Biologie Onderzoeksgroep Natuurbeheer Contact person: Prof. R.F.Verheyen, verheyen@uia.ua.ac.be

7. Eco-physiological study of a forest ecosystem subjected to elevated CO_2 concentrations, in rooms with open sky.

Scope
The aims of this project are:
A. Study of the influence of concentrations raised out of CO_2 on the physiological mechanisms which determine the growth, the use of water and the potentialities forest as well with CO_2.

B. Contribution to the knowledge of the processes - on the level of the ecosystem, of regional forest solid masses, even on the level of a continent - which intervene in the role of the forest as well with CO_2 and which makes it possible to consider the forest like a regulator of the rate of rise in the content atmospheric CO_2.

The PROJECT gathers at the same time a simulation in natural conditions on trees acclimatised to the conditions of culture - rooms of simulation with sky open in our experimental piece of Large-Wood (Vielsalm) - and the development of predictive models, on a forest piece scale on the one hand and on the scale of the moderate forest (recourse to the computer). This last level of investigation could not be approached that with the help of a profitable collaboration within the framework of program EPOCH.

Duration: 01/Dec/1990 - 30/Nov/1994	
Promoter:	Faculté des Sciences Agronomiques à Gembloux - U.E.R. de Biologie végétale Contact person: Prof. R. A. Impens

8. Biogeochemical Cycles of Forest Ecosystems Related to Global Change and Sustainable Development

Scope
The goal of this proposal is to generalise previous experimental observations of impacts of CO_2 and temperature on trees to evaluate their likely impacts on forest ecosystems in view of their sustainable development. The deliverables include:

- the establishment of an extended inventory and the fundamental analysis of the available and acquired data related to carbon, nutrient and water cycles in typical Belgian forest ecosystems (e.g. functional types);
- the validated modelling of the pools and the fluxes under current conditions, including the scaling up to the level of the landscape unit and the region;
- the predictions of changes in the pools and the fluxes, under a series of realistic climatic scenario's, in view of a future sustainable development of Belgian forest ecosystems, including the formulation of relevant guidelines;
- the establishment of an integrated data base with easy access (CD-ROM), containing all experimental and simulated information on the biogeochemical cycles in Belgian forest ecosystems.

The analysis of the carbon, nutrient and water cycles of Belgian forest ecosystems will start from the inventory of observations made in 6 different experimental sites, corresponding to the major forests of Belgium (Functional forest types). The sites have been selected according to the existing basic knowledge on ecosystem functioning. A large amount of biogeochemical data is already available for the selected sites, and some of them are still operated within related research projects funded by the EU or the Belgian Regions.

The project revolves around 5 Task forces. The biogeochemical cycles in the forest ecosystems are considered as an interaction of carbon, nutrients and water cycling, driven by the uni-directional flow of energy. Data will be carefully checked, validated and introduced into a data base. Consecutive levels of investigation (leaf, whole tree, stand, catchment, region) cover a sequence of time-space domains for which up- and down- scaling techniques in modelling are required. Carbon, water, nutrients, data base modelling are the five task forces of the project.

It is expected that the study will yield a fundamental framework for the future Belgian forest policies, based on a realistic ecosystem approach which guarantees a sustainable development of our forest resources.

Duration: 1/Dec/1996 - 30/Nov/2000	
Organisations involved	Universiteit Gent, Laboratorium voor Plantecologie Contact person: Prof. R. Lemeur, Raoul.Lemeur@rug.ac.be
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	Université de Liège, Institut d'Astrophysique, Lab. De Physique Atmosphérique et Planetaire Contact person: Dr. L. Francois, francois@astro.ulg.ac.be) Prof. J. C. Gerard, gerard@astro.ulg.ac.be
	Flemish Institute for Technological Research Contact person: Dr. F. Veroustraete, veroustf@vito.be Dr. J. Van Rensbergen, vrensbej@vito.be
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DENMARK

1. Effects of climate change and air pollution on carbon and nitrogen storage and productivity in Scandinavian forest ecosystems (NORDSOIL)

Scope
NORDSOIL is a database project that aim to compile already existing analytical soil profile data and ecological data at the site level in a database. Carbon and nitrogen storage (kg/m^2) in the soils are calculated from the data. The results are analysed and interpreted in relation to the climate gradient found throughout the northern countries from latitude 54º to 70º and longitude from 8º to 25º. In this way the effect of possible climate changes on soil carbon and nitrogen storage can be evaluated and discussed.

Duration: 1996 - 1998	
Organisations involved	Forest and landscape Research Institute, Department of Forest Ecology Contact person: Prof. K.R. Rasmussen, krr@fsl.dk
	University of Helsinki, Department of Forest Ecology Contact person: Prof. C.J. Westman, Carl.J.Westman@Helsinki.fi
	Institut for Jord og Vannfag, Norway Contact person: Prof. G. Abrahamsen, Gunnar.Abrhamsen@ijvf.nlh.no
	Swedish University of Agricultural Sciences, Department of Forest Soil Contact person: Prof. M. Olsson, Mats.Olsson@sml.slu.se

FINLAND

1. The Finnish Research Programme on Climate Change (SILMU)

Scope
The SILMU project, already completed, was carried out over the six years 1990-1995.
This project was a multidisciplinary national research programme on climate and global change. The principal goals were:

- to increase our knowledge on climate change, its causes, mechanism and consequences;
- to strengthen the research on climate change in Finland;
- to increase the participation of Finnish researches in international research programmes;
- to prepare and disseminate information for policy makers on adaptation and mitigation.

The key areas were:

- quantification of the greenhouse effect and the magnitude of anticipated climatic changes;
- assessment of the effects of changing climate on ecosystem;
- development of mitigation and adaptation strategies.

The final report has been published by the Academy of Finland and may be ordered from: Academy of Finland, Vilhonvuorenkatu 6, PL 99, 00501 Helsinki, Finland

Overview of the project in PDF format: http://www.aka.fi/silmu/silmu2.html

2. Climate Change Research

Scope
The need for reliable long-term climatic records has recently increased in connection with the studies of the potential climatic effects of anthropogenic and natural forcing factor relationships in climatic fluctuations. The greatest potential climatic changes are expected to occur in the high latitudes.

A joint Nordic climate project is working with the aim of building a reliable climatological data set. The data set will comprise stations representing the northernmost long-term records of fixed stations in the world. As a part of the Nordic co-operation as well as a contribution to the Finnish Research Programme on Climate Change (SILMU), extensive studies have been made on the climatic data, data homogeneity and climatic changes in Finland during the instrumental period.

A new study (REWARD) has been started recently jointly with all the Nordic countries. It is related to climatic extremes and sponsored by the Nordic Council of Ministers.

On-going and future work in the climate applications research area is planned to direct to the following topics:

- hydrometeorological studies, including also evapotranspiration in all main land types and detailed maps of water balance components for the period 1961-1990.
- a complementary study of the "the national climatic change"
- human ecology in historical times in Finland, particularly in relation to climate
- a comprehensive study of the snow cover periods in Finland, comprising both regional and temporal distributions; in map analyses Kriging method is applied.
- research on snow depth observations paying attention both to temporal and regional distributions as well as ecological and economical relationships and applications.

More information: http://www.fmi.fi/TUT/MET/ilmasto/ilm_engl.html

Promoter: Finnish Meteorological Institute, contact person Mikko Alestalo, mikko.alestalo@fmi.fi

GERMANY

1. Potential Effects of Climatic Changes on Soil water Status and Drought Stress Susceptibility of Norway Spruce Stands in the German Alps

Scope
Predictions on future climate revealed increasing drought stress for Middle European vegetation because of decreasing precipitation and increasing temperatures esp. in summer. The meteorological conditions of southern Bavaria are somewhat unique in relation to other Central European areas and have to be considered when evaluating the specific situation of the German Alps. The aims of this project are thus:

- Modelling of forest growth of Norway spruce stands in the Alps under different climatic conditions based on the relation between xylem water potential and growth
- Beside changes in temperature and precipitation, an increase of atmospheric CO_2 is to be expected. This might cause an increased water use efficiency of the trees which might compensate the increased evaporational need. By coupling our soil water model to a physiologically based transpiration model we will be able to include different water use efficiencies in our scenarios.
- The assessment of drought stress susceptibility derived from single stands will be extrapolated to larger areas of the German Alps based on soil survey data. The identification of high risk areas will be useful for forest management in the future.

Duration: 01/Jan/1997 - 31/Dec/1998 More information: http://www.bitoek.uni-bayreuth.de/Forschung/Projekte/EN.html	
Promoter:	University of Bayreuth, Department of Soil Ecology Contact person: Prof. Egbert Matzner, Egbert.Matzner@bitoek.uni-bayreuth.de Prof. Bernhard Manderscheid, Bernhard.Manderscheid@bitoek.uni-bayreuth.de

2. Qualitative Dynamics of Syndromes and Transition to Sustainability (QUESTIONS)

Scope
The goal of the QUESTIONS project is to analyse and to model the syndromes of Global Change (GC) on the basis of expert knowledge and intuition as well as of quantitative and qualitative data. Syndromes defined as archetypal patterns of civilisation-nature interaction are assumed to represent the most appropriate entities for a comprehensive analysis of the complex phenomenon Global Change (Schellnhuber et al., 1997). The results on every single syndrome refer to a detailed system analysis of the corresponding interaction pattern. The analysis which is based on a vocabulary of about 80 trends or symptoms of Global Change is aiming towards:

- the formulation of a syndrome-specific network of interrelations between these trends,
- a geographically explicit determination of the disposition towards the syndrome and of the intensity by which the syndrome-specific mechanisms of civilisation-nature interaction are active in the region considered,
- the specification of a set of exposition factors which can serve as triggers for the start of the mechanisms,
- a qualitative model of the dynamics of the syndrome which enables a weak projection of its future evolution (this has to be done in the final phase).

The overall analysis of all syndromes allows the explanatory potential of the entire approach to be checked: if it is possible to explain the observed dynamics of the core problems of GC by the specified set of syndromes, then this potential is high. As, however, syndromes include the entire cause-effect patterns it is more than just a mere explanation: it can help to identify those 'screws' which are most effective with respect to a transition to sustainable development.

Duration: 1995 - 2000 More information: http://www.pik-potsdam.de/cp/quest/	
Organisations involved	German Advisory Council on Global Change (WBGU), Integrated Systems Contact person: Dr. Arthur Block
	Federal Ministry for Education, Science, Research and Technology (BMBF), Integrated Systems Contact person: Dr. Martin Cassel-Gintz
	Rheinish, Westphaliaan, Institute for Economic Research, Essen Contact person: Dr. Jochen Dehio
	Potsdam Institute for Climate Impact Research (PIK) Contact person: Dr. Jürgen Kropp Dr. Gerard Petschel-Held
	MPI Meteorology, Hamburg Contact person: Dr. Gerhard Lammel
	Univ. Marburg, Department of Public Finance Contact person: Dr. Wiebke Lass
	Univ. Dortmund, Department of Spatial Planning Contact person: Dr. Roger Lienenkamp
	Secretariat of the WBGU, Bremerhaven Contact person: Dr. Carsten Loose
	BMBF, Integrated Systems Contact person: Dr. Matthias Lüdeke Dr. Oliver Moldenhauer
	BMBF, Social Systems Contact person: Dr. Fritz Reusswig
	Institute for Soil Research and Forest Nutrition, Univ. Göttingen Contact person: Dr. Hubert Schulte- Bisping

3. Climate Research

Scope
The mission of the Climate Research Department has changed since the early years of the institute. In the beginning, mere supply of climate data and climate scenarios to the impact research community was its main topic. Meanwhile, the Climate Research Department has come to address basic problems related to diagnosis of climate data, construction of climate change scenarios as well as climate system modelling.

1. Climate Analysis and Diagnosis
A prerequisite for any research related to climate is a thorough analysis of present-day climate. This concerns not only "simple" climatic mean values, such as, for example, monthly mean temperatures and annual mean precipitation. Instead, for many applications in climate impact research, information about climatic extremes, such as strength and duration of cold spells or rainfall events etc., is needed. Therefore, methods for the statistical description of extreme climate events have been developed and used in the Climate Research Department.

Similar methods which are employed for the analysis and diagnosis of climate data are applied to the validation of climate models. This serves not only to improve climate models, but also to achieve a better understanding and more appropriate exploration of model results in climate impact research.

For the sake of a comprehensive climate analysis and diagnosis the Climate Research Department collects meteorological data being observed on a daily basis from climate stations world-wide. These data are regularly extended, updated, checked for quality, and stored in a Meteorological Data Bank which is available to all core projects of the institute as well as research partners.

2. Climate Scenarios
To explore the impact of any climate change - regardless of its origin, be it natural or anthropogenic - on natural and social systems, climate, or climate change scenarios have to be formulated. A scenario is not a forecast. Because the climate system is influenced by anthropogenic activities, e.g. emission of greenhouse gases and changes in land use, and because these activities are hardly predictable, the climate itself cannot be forecasted. Instead, estimates of possible climate developments - climate scenarios - are computed, based on various estimates of socio-economic changes and associated changes in the emission of greenhouse gases - so-called

emission scenarios. Tools for construction of climate scenarios are numerical climate models, statistical models, and combinations of both. In the Climate Research Department, three general types of methods have been developed and used.

The first method is based on climate models only. Global climate models provide reliable information at rather coarse spatial scales, say at the scale of continents. To arrive at a scenario for smaller regions, say a state or a river drainage basin, one has to transform this information to the scale in question. The method of so-called dynamic downscaling makes use of a regional climate model which is embedded into the global model and which is run at a much higher spatial and temporal resolution than the global model. Adaptation of a regional model to selected regions of the world and validation of the adapted model as well as regional climate simulations are undertaken by the Climate Research Department.

The second method, the so-called expanded downscaling, is based on climate model results - either global or regional climate models - which are transformed to smaller scales by using statistical methods, thereby providing climate scenarios at scales at which the numerical model is unreliable.

The third method is a coupled statistical model which combines results of climate models and observations. In this method, observed long-term time series of meteorological data are prepared by statistical methods in such a way that they reflect changes computed by climate models.

3. Climate System Modelling

The study of climate change not only involves the analysis of recent climates and estimates of possible future climates of the next decades and centuries, but it also addresses the fragile balance between various components of the climate system such as the atmosphere, the hydrosphere (mainly ocean and rivers), the cryosphere (mainly inland ice, permafrost, and snow), the terrestrial and marine biosphere, and the lithosphere (part of the Earth's upper mantle), which particularly includes the pedosphere (mainly the soils).

In the Climate Research Department, a reduced form climate system model, CLIMBER (for CLIMate and BiospheRE), has been developed. In contrast to comprehensive climate models, which are currently set up at other institutes like the Max-Planck-Institute for Meteorology in Hamburg or the NCAR (National Center of Atmospheric Research) in the USA, CLIMBER is not meant to describe in detail and with the highest possible spatial and temporal resolution some components of the climate system. This requires vast computer power and data storage (a 100-year simulation would take approximately half a year on a super-computer.) Instead, attention is focused on the interaction between all components of the climate system. Therefore, CLIMBER has been developed to provide a rather coarse-scale, but very efficient description of the climate system. It is at least 1000 times faster than the comprehensive models and, therefore, suitable for climate system analysis. Moreover, CLIMBER will become a component of the Potsdam Earth System Model.

Using CLIMBER, questions will be addressed which concern the role of the vegetation in the climate system as well as the strong climate variability of the recent geological past, for example variations in the North Atlantic ocean circulation - which, if they happened today, would be a catastrophe to humanity.

More information: http://www.pik-potsdam.de/dept/cli/

Potsdam Institute for Climate Impact Research (PIK), Department of Climate Research
Contact person
Head: Prof. Martin Claussen
Deputy Head: Prof. Friedrich-Wilhelm Gerstengarbe
Staff and Guests: Eva Bauer, Uwe Böhm, Victor Brovkin, Gerd Bürger, Andrey Ganopolski, Claudia Kubatzki, Hermann Österle, Vladimir Petoukhov, Stefan Rahmstorf, Peter Werner, Ursula Werner

4. Integrated Assessment of Climate Protection Strategies (ICLIPS)

Scope

The ICLIPS project is an international and interdisciplinary research activity which seeks to provide an Integrated Assessment of Climate Protection Strategies by using a new method: the Tolerable Windows Approach (TWA). To this end, the project brings together experts from leading research institutions in the field of global climate change under the leadership of the Potsdam Institute for Climate Impact Research (PIK), which has initiated the project and which will integrate the various model components within the framework of the Tolerable Windows Approach. The main objective of the ICLIPS project is to develop methods, collect data, and elaborate models needed to support the international decision-making community in the difficult choices faced in the realisation of the Framework Convention on Climate Change (FCCC) and the Berlin Mandate.

The Tolerable Windows Approach is based on the specification of tolerable sets of climate impacts, allowances and instruments for implementation. The related "tolerable windows" are derived successively in an inverse mode: by first analysing the additional stress levels caused by climate change that one can assume to be ecologically and socio-economically bearable, a tolerable window for future climate development is deduced. In a further step, the corresponding set of admissible emission profiles is calculated, i.e. those global greenhouse gas emission paths which keep the climate system within the demarcated window. From among the family of emission options so-defined, specific strategies are finally filtered out by feasibility criteria which constitute the aforementioned tolerable set of allowances and instruments.

The ICLIPS project involves the coupling of regionalized models for:

- the impact of climate on natural and managed ecosystems as well as on human societies
- natural biogeochemical cycles, climate, greenhouse gas and aerosol emissions
- instruments representing climate policy measures and influencing socio-economic development.

The main objective for the initial phase (1996/1997) of the project has been the development of a global integrated model in order to study the principle issues related to the conceptual basis of the tolerable windows approach, to develop appropriate mathematical techniques, and to introduce first results in the international platform of the IPCC as well as in the scientific discussion of the German Advisory Council on Global Change (WBGU) which is nominated by the German government.

Duration: 1996 – 1999 More information: http://www.pik-potsdam.de/cp/iclips/	
Organisations involved	Potsdam Institute for Climate Impact Research (PIK) Contact person: Prof. Dr. Ferenc Tóth, (Economics and Policy Analysis, Project Leader) Dr. Thomas Bruckner (Theoretical Physics, Conceptual Design and Climate Modeling) Dr. Hans-Martin Füssel (Systems Science, Data Base Management and Impact Modeling) Carsten Helm (Economics, Political Science) Dr. Marian Leimbach (Economics, Economic Modeling) Dr. Gerhard Petschel-Held (Theoretical Physics, Conceptual Design) Prof. Dr. Hans-Joachim Schellnhuber (Theoretical Physics, Director of PIK)
	Environmental Systems Research Center, University of Kassel Contact person: Prof. Dr. Joe Alcamo
	Battelle Pacific Northwest National Laboratories, Washington Contact person: Dr. Jae Edmonds
	Max Planck Institute for Meteorology, Hamburg Contact person: Prof. Dr. Klaus Hasselmann
	Kiel Institute of World Economics, Kiel Contact person: Dr. Gernot Klepper
	IIASA, Luxembourg, Contact person: Dr. Nebojsa Nakicenovic
	Jackson Environment Institute, University College, London Contact person: Prof. Martin Parry
	Wuppertal Institute for Climate, Environment and Energy Contact person: Prof. Dr. Peter Hennicke
	Electric Power Research Institute, Palo Alto, CA, Contact person: Dr. Richard Richels
	IIASA, Laxenburg, Contact person: Dr. David Victor
	German Institute for Economic Research, DIW, Berlin Contact person: Dr. Hans-Joachim Ziesing
	Institute for Energy Economics and the Rational Use of Energy, Stuttgart Contact person: Prof. Dr. Alfred Voß

IRELAND

1. Peatlands Carbon Balance Project

Scope

Northern peatlands occupy some 346 million hectares and play an important role in the global climate. They release considerable amounts of methane and sequester large amounts of carbon dioxide. In Europe 15 million hectares of peatlands have been drained for forestry. Research interest has grown about the impact of peatlands drainage on the carbon balance and the role of peatlands forests in the global climate. This project involves research at Cloosh Valley Forest, Connemara to investigate some of these impacts. Carbon dioxide emissions are being monitored across a range of sites, open peatlands, recently afforested, mature forest and recently clearfelled. During measuring campaigns the water table level is measured at all sites and soil temperature is constantly monitored at a small number of sites. These measurements will enable carbon dioxide emissions to be modelled and estimates of the annual carbon dioxide flux to be calculated based on soil temperature measurements.

Other elements of the project are:

- a litter bag experiment to assess the rate of decomposition and nutrient leaching at all sites,
- controlled laboratory studies using cores of peat to assess the quantitative impact of water table depth and soil temperature on carbon dioxide emissions.

More information: http://www.ucd.ie/~ferg/Research/Projects/Peatlands_Carbon_Balance.html	
Promoter	University College of Belfield, Department of Environmental Resource Management, Forest Ecosystem Research Group Contact person: Mr Kenneth A. Byrne, byrneka@agriculture.ucd.ie Prof. E.P. Farrell, ted.farrell@ucd.ie

ITALY

1. Searches on the impact of the environmental changes in Mediterranean forests

Scope
The search has followed two various methodological approaches: one experimental and the other modellistico. The experimentation has been lead in one Mediterranean spot of holm-oak subordinate from various years to atmosphere enriched from CO_2 in order to simulate the effect of the progressive increase of concentration of CO_2 in the atmosphere. The observed ecosystem processes have been the increase of the wood and foliar member of the arboreal and shrubby plants, the production of litter and its degradation, the composition nourishing biochemistry and of the litter, the radical productivity, the respiration of the land, the water state of the plants and the land. The modellistico approach has been applied both to the holm-oak forest and to an European beech forest with the aim of validating models of gaseous exchanges (CO_2 and H_2O) to level of forest covers with the measures realised with the technique of the "turbulent correlations ".

Promoter:
Universitá degli Studi della Tuscia, Dipartimento di Scienze dell'Ambiente Forestale e delle sue Risorse
Contact person: Dr. G. Scarascia Mugnozza, gscaras@unitus.it

2. University of Padova, Dept. TeSAF (Land and Agroforestry Systems)

Scope
A peripheric structure of this Dept. is the «Study Centre for the Alpine Environment" of S. Vito di Cadore (BL) in the Dolomites, that hosts a laboratory for soil and water analysis. A "Timberline ecology research unit" was formed to carry out research on long and short term relationships between forest species growth and climate dynamics at timberline. This research integrates eco-physiological and dendroecological methods.

The group controls two monitoring stations located at different altitudes: Col de la Roa (1100 m) and 5 Torri (2080 m). The first one is a meteorological station (air temperature; total radiation; photosynthetic active radiation; precipitation; relative moisture; atmospheric pressure, wind speed and direction) equipped with some air and precipitation quality sensors (ozone and sulphur dioxide concentration; pH of precipitation).

The second one is also monitoring soil temperature and water content and several functional parameters of the main timberline species (*Picea abies*, *Larix decidua*, *Pinus cembra*), such as: tree leaf and branch temperatures, stem radial growth, sap flow density and velocity.

The research group has partecipated, between 1994 and 1996, to a National project funded by the Ministry of University and Scientific Research, about the effects of climatic and land-use changes on forest ecosystems structure and functions, taking care of high altitude forests.

Since 1998 the research group is one of the operating units within the UE project FORMAT (ENV4 CT97 0641) (see specific chapter for detailed information).

More information: http://www.unipd.it/main/strutt.html	
Contact persons	Dr. Carlo Urbinati, urbinati@ux1.unipd.it Dr. Tommaso Anfodillo, anfodill@ux1.unipd.it

NETHERLANDS

1. Netherlands Climate Change Studies Assistance Programme

Scope

The Netherlands Climate Change Studies Assistance Programme is an initiative of the Netherlands Government, Ministry of Foreign Affairs, Directorate General for Development Co-operation and started in 1996.
The aim of the programme is to enable developing countries to create a greater awareness of climate change issues and to increase the involvement of policy makers, scientists and the general public. To reach this goal, the Programme enables the responsible ministry, mostly the Ministry of Environment, to initiate climate change studies which are carried out by appropriate scientific institutions.

These studies may include a variety of topics, such as greenhouse gas emission inventories, mitigation (emission reduction) studies, assessments of climate change impacts and adaptation options, and the compilation of the National Communication. The scope of the studies depends on national needs, priorities, experiences and expertise. The studies should contribute to the implementation of the United Nations Framework Convention on Climate Change (UNFCCC) and the National Communication of the participating countries.

Since it is expected that impacts of climate change will be most severe in developing countries and thereby may hamper sustainable development, the Netherlands programme provides opportunities to carry out in depth climate change impact and adaptation studies. The majority of the studies under the Netherlands programme deals therefore with climate change impact assessments, and the identification of possible adaptation options. These studies complement other climate change studies, such as greenhouse gas emission inventories and mitigation studies.

It is the intention and hope of the Netherlands Programme that the results of the climate change studies will find their way into national sustainable development plans and environmental action plans of the countries participating.

The Institute for Environmental Studies (IVM), Vrije Universiteit, Amsterdam is contracted to manage the Netherlands Climate Change Studies Assistance Programme.

The co-ordination of the country studies is divided between the IVM and the Netherlands Coastal Zone Management Centre (CZMC). The IVM co-ordinates the studies related to emission inventories, mitigation, and impact and adaptation regarding agriculture and forestry. It co-ordinates the country studies focusing on these issues (Bolivia, Ghana, Senegal, Yemen, Kazakstan, Mongolia and Bhutan), and it will also co-ordinate the activities related to these issues between countries. The CZMC co-ordinates the activities in those countries which have a coastal zone study as the main part of the climate studies (Costa Rica, Ecuador and Surinam). It also co-ordinates the coastal zone and water resources studies between countries.

Since capacity building and institutional strengthening are very important aspects of the Netherlands programme, a prerequisite is that the studies are being carried out by institutions and scientists of the participating country. To assist the national study teams, the Netherlands programme has contracted international consultants for each specific sector of the climate change studies. These consultants are available to the national study teams for technical assistance/backstopping, advise and training. To facilitate communication between study teams of various countries and international consultants, the Netherlands programme provides, if needed, email and internet connections and to a certain extent the necessary hardware and software.

After formal inclusion in the Netherlands Climate Change Studies Assistance Programme by the Netherlands Ministry of Foreign Affairs (Directorate General for Development Co-operation), the national focal point of the country elaborates a detailed project proposal, in close co-operation with the management of the programme. This will contain the organisational framework of the country study, project descriptions, terms of references, workplans and budgets.

Besides technical sectoral studies, the country studies include two or three national workshops where scientists and policy makers meet to exchange information regarding the set up of the studies and preliminary results, and to discuss the implications for policy makers.

Besides national workshops, the programme provides regional workshops or bilateral meetings between countries. This will enable scientist and policy makers to meet with country teams of other countries and to strengthen (regional) networking.

At the start, the Netherlands Climate Change Studies Assistance Programme included 7 countries: Bolivia, Costa Rica, Ecuador, Ghana, Senegal, Surinam and Yemen. In the mean time, three other countries joined the programme: Mongolia, Kazakstan and Bhutan. It is expected that Colombia and Zimbabwe will participate in the near future. The next section gives an overview of current country studies.

Duration: 1996 - to define More information: http://ohrid.cca.vu.nl/english/o_o/instituten/IVM/projects/research/ClimateChange/index.html	
Organisations involved	Vrije Universiteit, Institute for Environmental Studies Contact person: Dr. Jan F. Feenstra, Jan.Feenstra@ivm.vu.nl
	Netherlands Ministry of Foreign Affairs, Directorate-General for Development Co-operation, Environment Directorate Contact person: Ton Boon von Ochssee, ochssee@dml.minbuza.nl

2. Dutch National Research Programme on Global Air Pollution and Climate Change (NRP)

Scope
The NRP is a programme for the encouragement and financing of climate research, conducted by a variety of universities and institutes. More than 30 Dutch research institutes are working on problems that, directly or indirectly, have to do with climate change and 'global change'. Within the NRP programme are developed several specific research projects; below there are some of the main topics and a short description of some projects.

Climate change and forest ecosystem dynamics: carbon and water relations, competitions, and consequences for forest development and forest use. Carbon and water relations of forest ecosystems and long-term consequences of global climate change on forest development and potential forest use are assessed using models of forest primary production, forest hydrology, and succession models of long-term forest development, in combination with experimental data on effects of CO_2 and temperature on ecosystem processes. The models are hierarchically nested, with summary models derived from detailed process-based models to describe long-term impacts of climate change. Hydrological models and succession models are compared to European and national monitoring data. Primary production models are used to quantify competition between the main tree species; simulated forest development is interpreted in terms of recreational value, wood production, and value for biodiversity; climate change impacts on potential forest use is assessed in scenario studies. Impacts of climate change is analysed for a range of representative forest ecosystems in Europe; implications for forest management and forest use will be assessed with main emphasis on forest types representative for Dutch conditions.

IBN - DLO Bos- en Natuurontwikkeling
Contact person: Dr. G.M.J. Mohren, g.m.j.mohren@ibn.dlo.nl

Development of economy/energy/environment models to support IMAGE development and applications
Economy/energy/environment interactions are a keystone element of integrated climate change assessments, within IMAGE addressed in the Energy-Industry Subsystem (EIS). This project aims to support further development of the EIS, by developing further the existing MARKAL-MACRO toolbox, combining a technological energy/environment process model with a macro-economic model at the national level. The resulting tool will cover relevant aspects of the relations between general, economy-wide developments, energy supply, conversion and demand, and emissions of greenhouse gases. Assessments of these relationships, building on results from similar national models applied to a wide variety of economies, will be used to support development of the EIS of IMAGE. This will include suggestions of further improvement and assistance to underpin regional scenarios. In order to ensure ease-of-use and facilitate portability, the models will be implemented on PC's and operated under suitable user interfaces for data management, scenario management and analysis of results. The tool can be used to address policy questions arising from the project "Climate change between science and policy: optimizing the toolbox" (R. Swart, RIVM), supplemented by experience and

knowledge of ECN-PS in the areas of national and international energy (technology) strategies for reduction of greenhouse gas emissions.

ECN – Beleidsstudies
Contact person: Dr. T. Kram, kram@ecn.nl

Municipal climate change policies: a case study for Amsterdam
This project covers the possibilities and effects of municipal policy for reduction of greenhouse gases, in this case within the sphere of influence of the authorities of Amsterdam. On the one hand municipalities are willing to contribute to the reduction of environmental problems like emission of greenhouse gases. On the other hand they are sometimes forced more or less to act against these policy aims, for instance because of infrastructure requirements. Moreover, long term environmental effects form only one of the many issues that local policy and local planning have to cope with. As the long term effects are not easy to see, short term effects of policy might have priority in the decision processes. To estimate the long term effect of decisions on greenhouse gas emissions, the project focuses on local policy, local plans and local planning, on construction of scenarios for greenhouse gas emissions for the city of Amsterdam and on the communication of these scenarios with local policy makers. These local policy makers will form a reference group that will steer the process of scenario construction. The scenarios will be drawn to provide insight in the main factors that drive future greenhouse gas emissions, to show what the options are to reduce emissions of Amsterdam, to identify the main barriers for such options and to develop implementation strategies for three most promising policy options. A general approach for assessing local policy options will be established.

ECN Beleidsstudies
Contact person: Dr. E. Schol, schol@ecn.nl
More information: http://www.nop.nl

3. Greenhouse effect and climate change: causes, effects, and measures

Scope
One of the most important current environmental issues is the ongoing change in the chemical composition of the atmosphere and the observed and expected changes in climate. This "Greenhouse Issue" raises many questions and crosses traditional borders of countries and of scientific disciplines, even more so than most other environmental problems.

To study the chain of "causes, effects and measures", an interdisciplinary research programme on the greenhouse issue has been formulated in WIMEK, which is carried out jointly with several DLO-Institutes. The programme is focused on the interactions between the landscape-system (both natural and cultivated systems) and atmospheric changes (both changing concentrations of greenhouse gases and climate).

The main goals of the programme are (1) to reduce scientific uncertainty concerning the causes and effects of climate change, and (2) to improve predictions and to draw conclusions concerning anticipating measures, especially regarding the implications of climate change for future land use, physical planning and environmental management.

Expertise in this programme comes from natural sciences (e.g. meteorology, atmospheric chemistry, soil science, terrestrial ecology, water management) and socio-economic sciences (e.g. sociology, environmental economics, household and consumer studies). The research methods include empirical studies (experiments, observation), development of methods and theories, and systems analysis and policy-oriented decision-support research (e.g. scenario-analysis and modelling).

To strengthen links between separate, often disciplinary projects, six working programmes have been formulated around the following topics:

1. working and monitoring of the climate system;
2. formation and emission of greenhouse gases;
3. physiological effects on soils and plants;
4. effects on ecosystem stability and biodiversity;
5. consequences for land use and water management;
6. socio-economic aspects and policy implications.

More information: http://www.wau.nl/cmkw/wimek.htm
Wageningen Centre for Environment and Climate Studies (WIMEK)
Contact person: Prof. L. Hordijk , Leen.Hordijk@wimek.cmkw.wau.nl

PORTUGAL

1. Climate Change in Portugal in the last 15.000 years

Scope
The aim of this project is to achieve a first synthesis on the climatic evolution of Portugal in the last 15.000 years.

Main source of evidence:
- Palynological/macropalaeobotanical series obtained from the microstratified organic deposits in lakelets and peatmires from the Serra de Estrela, North-Littoral of Alentejo, and Littoral of Estremadura;
- Dendroclimatic series in pine wood.
- The reconstruction of paleoclimatic parameters will be supported by Numerical Analysis.

Duration: 01/May/1997 - 30/Apr/1999	
Organisations involved	Fundação da Faculdade de Ciências da U.L. Contact person: Prof. Felipe Duarte Santos
	Instituto de Ciência Aplicad e Tecnologia (U.L.)
	Instituto Tecnológico e Nuclear

SWITZERLAND

1. Alpine Climate Change

Scope
The present and future climate of the Alpine region is in effect the response to, and the modification of, the prevailing large-scale weather patterns. The main objective of this project is to develop and use a regional scale climate model both to determine the reproducibility of the present Alpine climate and thereby make available a tool for the study of the regional response to various scenarios for global climate change.

Promoter
Swiss Federal Institute of Technology (ETH), Zurich, Laboratory for Atmospheric Physics, Department of Environmental Sciences
Contact person: Prof. H. C. Davies, davies@atmos.umnw.ethz.ch
Dr. D. Lüthi (Atmospheric Science ETH)

2. Alpine Climate and Climate Change: A Study of some Key Atmospheric Processes

Scope
Global change is likely to affect the Alpine environment not only through the projected warming itself, but also through changes in the distribution and frequency of precipitation. The Alps as a major topographic barrier exert a pronounced impact on this variable through various topographically-controlled precipitation mechanisms. The current study is designed to seek fundamental understanding of the key atmospheric processes which shape the regional precipitation distribution in response to the larger scale atmospheric circulation.

The prime objectives are to:

- evaluate the predictability of the regional climate with special regard to precipitation
- assess the sensitivity of critical atmospheric processes with respect to global change.

To this end, high-resolution regional climate simulations with a sophisticated weather forecasting model are conducted. The utilised horizontal resolution corresponds to between 14 and 56 km. The simulations are driven by and validated against observed data. In addition, sensitivity studies are carried out in order to assess the effects of putative climate change. The study contributes towards better estimates of climate change in the Alpine region, and it does pinpoint towards critical processes and their sensitivity to global change.

More information: http://www.umnw.ethz.ch/LAPETH/doc/model.html

Promoter
Swiss Federal Institute of Technology (ETH), Zurich, Laboratory for Atmospheric Physics, Department of Environmental Sciences
Contact Person: Prof. Dr. Christoph Schär, schaer@atmos.umnw.ethz.ch

3. Simulations of Global Climate and Climate Change with General Circulation Models

Scope
In a joint project with the Max-Planck-Institute for Meteorology (MPI), Hamburg, simulations of the global climate with the atmospheric general circulation model ECHAM are performed at the Swiss center for scientific computing, CSCS, Manno. The simulations are conducted with unprecedented high horizontal resolution at global scales (1.1°), a resolution previously restricted to numerical weather prediction models with short integration periods. The emphasis is on simulations for present-day conditions and climate change scenarios with increased levels of CO_2 concentration. The analysis of present climate simulations allows an estimate of the model accuracy and identifies weaknesses in the model parameterizations as guideline for further model improvement. The focus is on the radiation budget, on the surface hydrology and snow characteristics, and on the boundary layer structure. Furthermore the blocking performance of the model is evaluated. High resolution climate change experiments with doubled CO_2 concentration are used to study possible changes in the mass balance of the polar ice sheets and associated sea-level rise, and changes in the earth's radiation budget and in the

surface hydrology. Regional changes with focus on the Alpine areas are assessed in the framework of the EU project SIDDACLICH.

More information: http://www.geo.umnw.ethz.ch/klima/	
Promoter	Swiss Federal Institute of Technology (ETH), Zurich, Institute for Geography, Department of Environmental Sciences Contact person: Dr. Martin Wild, wild@geo.umnw.ethz.ch Peter Tschuck, tschuck@geo.umnw.ethz.ch Andreas Roesch, aroesch@geo.umnw.ethz.ch Prof. A. Ohmura

UNITED KINGDOM

1. CLIMEX

Scope
The objectives of CLIMEX are to:

- measure changes in plant CO_2 uptake, gas exchange and community phenology
- measure changes in forest growth and nutrient status
- measure changes in ground vegetation and nutrients
- determine changes in mineralization of soil organic matter
- determine changes in soil fauna and biologically mediated processes
- measure the effects of runoff water quality and quantity
- develop and validate process orientated models linking terrestrial and aquatic response.

CLIMEX is a unique integrated, whole-ecosystem research project, designed to monitor the response of entire catchments to increased CO_2 and temperature. This experiment is 100 times larger than previous whole ecosystem experiments of this kind. CO_2 and temperature are manipulated within the confines of a greenhouse so that the changes in mature forest growth and nutrient status can be measured insitu. The CLIMEX project allows the quantification of links between terrestrial aquatic ecosystems, providing data and information on the effect of climate change on natural forests, terrestrial ecosystems and water resources. These field observations form a base to improve and develop biogeochemical models so to evaluate the impact of future scenarios of climatic change. It is anticipated that the CLIMEX project will continue until 1998 so to link dynamic process studies of vegetation, soils, and soil fauna with large scale catchment measurements of hydrology, nutrients and gas fluxes. The results from this CLIMEX project contribute to the requirements of European policy for natural resource management and for determining national pollutant target emissions. The CLIMEX project also contributes directly to the IGBP/GCTE programme on the impact of global change on natural ecosystems.

Duration: 1994 - 1998 More information: http://www.mluri.sari.ac.uk/climex.htm	
Promoter	Macaulay Land use Research Institute Contact point: jinx@ua.nwl.ac.uk

5. CONCLUSIONS

This review could be considered like a tool for future research in the field of Climate Change. Indeed a short description is given for each project and, for the most of them, it is also indicated where it is possible to find more information on Internet.

In addition also the name and addresses of contact people are given in order to facilitate the contacts between different working groups.

The original idea was to present a complete overview of the ongoing projects, but unfortunately for some European countries there were not information available about this kind of research.

This happened mainly because of two reasons. The first one is that also if some countries participate in EU funded projects, they don't carry out research programs by themselves. Because of that, some countries are included as scientific partners in several European projects, but they don't appear in the list of the National projects.

The second reason is the difficulty to get information about these research programs, especially when they don't have web-pages. Indeed it is not always possible to contact directly the Institutes of Laboratories participating in a research projects and sometimes the information given are general and not always complete.

Nevertheless, to have a complete overview of the research situation in this field, the activities of some laboratories carrying out long-term research have been included. As they are continuously developed and updated, these research cannot be considered exactly like the other projects but their contribution to the research in this field seemed to be very important.

For the same reason also some projects already completed have been included, either because of the importance of the results or because they could be considered as starting point for new research.

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